Scilab Textbook Companion for Fluid Flow For The Practicing Chemical Engineer by J. P. Abulencia And L. Theodore[1]

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Book Description

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Scilab numbering policy used in this document and the relation to the above book.

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

AP Appendix to Example(Scilab Code that is an Appednix to a particular Example of the above book)

For example, Exa 3.51 means solved example 3.51 of this book. Sec 2.3 means a scilab code whose theory is explained in Section 2.3 of the book.

Contents

List of Scilab Codes

Chapter 2

unit and dimensions

Scilab code Exa 2.1 some basic conversion

```
//Example 2.1(1)
//Page no.10
printf("Example 2.1(1) Page no. 10\n\n")
//convert 8.03 yr to seconds
printf("8.03 yr =a\n\n")
yr=365//day
day=24//h
h=60//min
min=60//second
a=8.03*365*24*60*60
printf("8.03 yr is %f seconds \n\n",a)
//Example 2.1(2)
//Page no. 10
printf("Example 2.1(2) Page no.10\n\n")
//convert 150 mile/h to yard/h
printf("150 mile/h =x\n\n")
mile=5280//ft
ft=(1/3)//yd
x=150*5280*(1/3)
printf("150 mile/h is %f yd/h\n",x)
//Example 2.1(3)
```

```
//Page no. 10
printf("Example 2.1(3) Page no. 10\n\n")
//convert 100 m/s^2 to ft/min^2
printf("100 m/s^2 =a\n\n")
m =100//cm
cm=(1/30.48)//ft
min=60//sec
a=100*100*(1/30.48)*(60)^2
printf("100 m/s^2 is %f ft/min^2\n",a)
//Example 2.1(4)
//Page no. 10
printf("Example 2.1(4) Page no.10\n\n ")
//convert 0.03g/cm^3 to lb/ft^3
printf("0.03g/cm^3 =x\n")
g=(1/454)//lb
ft=(30.48)^3//cm^3
x=0.03*(1/454)*(30.48)^3
printf("0.03g/cm^3 is %f lb/ft^3\n",x)
```

Chapter 3

key terms and definitions

Scilab code Exa 3.2 determine the rise of the liquid in capillary tube

```
clc;
//Example 3.2
//Page no. 25
printf("Example 3.2 Page no. 25\n\n")
//given temperature(T),pressure(P),capilLary tube
    diameter(D),water density(rho),contact angle(
    ththetaeta)
sigma=0.0712//surface tension (sigma)of water at 30
    degree C temperature in appendix A.4
D=0.008
R=D/2
theta=0
g=9.807
rho=1000
printf("surface tension=%fN/m\n Radius=%fm\n theta=
    %fdegree\n g=%fm/s^2\n rho=%fkg/m^3\n",sigma,R,
    theta,g,rho)
h=(2*sigma*cos(0))/(rho*g*R)//height rise of the
    liquid
printf("height of liquid rise =%fm\n",h)
```

Scilab code Exa 3.3 find diameter of glass tube for the capillary height

```
clc;
//Example 3.3
//Page no. 26
printf("Example 3.3 Page no. 26\n\n")
//given at 30 degree temerature
//properties of water from appendix A.2 density(rho)
    ,surface tension(sigma)
rho=996
sigma=0.071
printf("rho=%f\kg/m^3\n surface tension (sigma)=%f N
    /m\n",rho,sigma)
theta=0//negligible angle of contact
g=9.807
h=0.001//less than one milimeter
printf("theta=%f degree \n g=%f m/s^2\n h=%f m\n",
    theta,g,h)
R=(2*sigma*cos(0))/(rho*g*h)//by capiilary rise
    equation
D=2*R
printf("R=%f m\n D=%f m\n",R,D)
//if the tube diameter is greater than 0.029075 mm,
    then the capillary rise will be less than 1mm
```

Scilab code Exa 3.4 determine the magnitude of the normal and parallel force components and the shear stress and the pressure

```
clc;
//Example 3.4
//page no. 28
printf("Example 3.4 page no 28\n\n");
```

```
S=2//surface area ft^2
F=10//magnitude of force,lbf
theta=%pi/6//angle
F_p=F*cos(theta)//parallel comp. of force
printf("\n F_p=%f lbf",F_p);
F_n=F*sin(theta)//normal comp. of force
printf("\n F-n=%f lbf",F_n);
tou=F_p/S//shear stress
P=F_n/S//pressure
printf("\n tou=%f psf\n P=%f psf",tou,P);
```

Scilab code Exa 3.5 determine the potential energy of water for 10 meter height

```
clc;
//Example 3.5
//Page no. 30
printf("Example 3.5 Page no. 30\n\n")
//determine potential energy of water
// given height,mass of water,g
m=1
g=9.8
Z1=0//at ground level
Z2=10//at 10 m above from ground level
printf("m=%f kg\n g=%f m/s^2\n Z1=%f m\n Z2=%f m\n",
   m,g,Z1,Z2)
PE1=m*g*Z1//potential energy at ground level
PE2=m*g*Z2//potential energy at 10m height
PE= PE2-PE1
printf("PE1=%fJ\n PE2=%fJ\n PE=%fJ\n",PE1,PE2,PE)
```

Chapter 5

newtonian fluids

Scilab code Exa 5.2 two parallel plates

```
clc;
//Example 5.2
//page no. 42
printf("Example 5.2 page no 42\n\n");
//To calculate the force to maintain movement of
    left plate
//velocity of moving plate is equal to the velocity
    of the plate and velocity of the gas at the
    surface of the stationary plate is zero
k=1.66//kinematic viscosity of gas
rho=0.08//density of gas
d=0.0833//distance between plate
v1=300//velocity of left plate
v2=0//velocity of stationary plate
g_c=4.17*10^(8)//gravitational constant
printf("given \n kinematic viscosity =%2f ft^2/hr\n
    rho=%2f lb/ft^3\n d=%4f ft\n v1=%f ft/hr\n v2=%f
    ft/hr\n gc=%f (ft*lb/hr)/lbf*hr",k,rho,d,v1,v2,
    g_c);
tou_xy=-k*rho*((v2-v1)/(g_c*d))//the frce necessary
    to mantain the movement of the left plate
```

```
printf("\n force tou_xy=%f  lbf/ft^2",tou_xy);
```

Scilab code Exa 5.3 couette and hatschek viscometer

```
clc;
//Example 5.3
//Page no. 45
printf("Example  5.3 page no. 45\n\n");
D=0.25//diameter of fixed inner cylinder of
    viscometer
L=0.5//height of fixed inner cylinder of viscometer
T=15.3//measured torque
printf("Given :\n diameter =%.2f ft\n height =%f ft\
   n Torque=%f ft.lbf",D,L,T);
F=(2*T)/D
printf("\n force =%f lbf",F);
//the shear stress(force parallel to the surface)
    using equation 5.11
tou=F/(%pi*D*L)
printf("\n shear stress tou=%f psf", tou);
```

Scilab code Exa 5.4 viscosities

```
clc;
//Example 5.4
//page no. 45
printf("Example 5.4 page no. 45\n\n");
//refer to example no 5.3
//determine dynamic viscosity and kinematic
    viscosity
omega=26.2//angular rotation speed
D=0.25//diameter of fixed inner cylinder of
    viscometer
```

```
v=omega*D/2
printf("\n omega=%f rad/s\n diameter D =%f ft\n
   linear velocity =%2f ft/s",omega,D,v);
d=0.001//clearance betwween two cylinder of
   visometer
vel. gradient =v/(d/12)//velocity gradient
gc=32.14//gravitational constant
printf("\n clearance d=%5f ft\n vel. gradient=%f 1/s
   \n gravitational constant gc=%3f ft/s*S",d,vel.
   gradient,gc);
tou=311.7//shear stress tou
meu=gc*tou/vel. gradient
printf("\n tou=%f psf\n meu=%f lb/ft*s",tou,meu);
rho=60.528//density of oil
neu=meu/rho//kinematic viscosity
printf("\n kinematic viscosity=%5f (ft*ft)/s",neu);
```

Chapter 7

conservation law for mass

Scilab code Exa 7.1 conservation law of mass

```
clc;
//Example 7.1
//page no. 64
printf("example no. 7.1 page no. 64\n\n");
//applying coservation of mass
// rate of mass in-rate of mass out+rate of mass
   generated=rate of mass accumlated
//according to conditions in this example
//rate of mass in = rate of mass out
Rf=4000//rate of feed of gaseous waste into an
   incinerator
Ra=8000//rate of air feed
Rm=550//rate of methane added for combustion
Rin=Rf+Ra+Rm//total rate of mass in
Rout=Rin//Rout is rate of mass out
printf("\n Rf=%f kg/hr\n Ra=%f kg/hr\n Rm=%f kg/hr\n
    Rin=%f kg/hr\n Rout=%f kg/hr",Rf,Ra,Rm,Rin,Rout)
   ;
```

Scilab code Exa 7.2 mass and volumetric flow rate

```
clc;
//Example 7.2
//page no. 65
printf("Example 7.2 page no. 65\n\n");
//water flowing through a converging circular pipe
   fig 7.3
//we have to determine mass and volumatric flow
   rates , mass flux of water
D1=.14// diameter of pipe at section 1
D2=.07//diameter of pipe at section2
v1=2//velocity at section
S1=%pi*(D1^2)/4//surface area at section 1
rho=1000//density of water
printf("\n diameter D1=%f m\n diameter D2=%f m\n v1=
   %f m/s\n Surface area S1=%f m^2\n density of
   water rho=%f  kg/m^3 ",D1,D2,v1,S1,rho);
q1= S1*v1//volumatric flow rate at section 1
m1=rho*q1//mass flow rate at section 1
G=m1/S1//mass flux at section 1
printf("\n volumatric flow rate q1=%f m^3/s\n mass
   flow ratem1=%f kg/s\n mass flux G=%f kg/m^2*s",q1
   ,m1,G);
S2=(%pi*D2^2)/4
q2=q1//q2 volumatric flow rate at section 2,due to
   steady flow q1=q2
printf("\n surface areaS1=%f m^2\n volumatric flow
   rate q2=%f m^3/s",S1,q1)
v2=(v1*S1)/S2//v2 velocity at section 2
printf("\n velocity v2=%f m/s",v2)
//conclusion :decrease cross section area results in
    an increase in flow velocity for an
   incompressible fluid.
```

Scilab code Exa 7.3 calculate mass flow rate at opening of flow device

```
clc;
//Example 7.3
//page no 66, fig. 7.4
printf("Example 7.3 page no 66,fig 7.4\n\n\n");
//fluid device has four openings as shoen in figure
//we have to calculate magnitude and direction of velocity ,mass flow rate at section 4
rho=800//density of fluid
v1=5//velocity at section 1
S1=0.2//surface area at section 1
v2=7//velocity at section 2
S2=0.3//surface area at section 2
v3=12//velocity at section 3
S3=0.25//surface area at section 3
S4=0.15//surface area at section 4
printf("\n velocity v1=%f m/s \n surface area S1=%f m^2/s\n velocity v2=%f m/s\n surface area S2=%f m^2/s\n velocity v3=%f m/s\n surface area S3=%f m^2/s\n surface area S4=%f m^2/s",v1,S1,v2,S2,v3,S3,S4);
q1=v1*S1//volumatric flow rate at section 1
q2=v2*S2//volumatric flow rate at section 2
q3=v3*S3//volumatric flow rate at section 3
printf("\n volumatric flow rate q1=%f m^3/s\n volumatric flow rate q2=%f  m^3/s\n volumatrisc flow rate q3=%f m^3/s",q1,q2,q3);
//applying continuity equation
q4=q1+q2-q3//volumatric flow rate at section 4
v4=q4/S4//velocity at section 4
printf("\n volumatric flow rate q4=%f m^3/s\n velocity v4=%f m/s ",q4,v4);
m=rho*q4//mass flow rate at section 4
printf("\n mass flow rate m=%f kg/s",m);
```

Scilab code Exa 7.4 mass balance in acontrol device

```
clc;
//Example 7.4
//page no 67, fig 7.5
printf("Example 7.4 page no, fig 7.5\n\n")
//Given pollutant in ppm in liquid stream ,some
    pollutant in discharge volume
//calculate what fraction of liquid bypass
//liquid stream having 600 ppm pollutant
//pollutant in the discharge stream is 50 ppm
//if B =factio of liquid bypassed,then 1-B= fraction
     of liquid treated
//performing a pollutant mass balance around point2
    in fig. 7.5
B=poly([0],'x');
N=roots((1-B)*0+600*B-50*1)
printf("\n\n calculation:\n  calculation  of liquid
     bypassed B=%.4f ",N(1));
```

Scilab code Exa 7.5 vertical tanl

```
clc;
//Example 7.5
//page no 67
printf("Example 7.5 page no 67\n\n")
//water flow in tank inletand outlet pipes
//applying continuity principle to the control
    volume
//since generation rate =0
d1=0.09//diameter of inlet pipe
v_in=4//velocity ,m/s
```

```
v_out=3//velocity ,m/s
q_in=(%pi*d1^2)*v_in/4//volumatric flow rate at
    inlet
d2=0.04//diameter of outlet pipe
q_out=(%pi*d2^2)*v_out/4
printf("\n diameter at inlet d1=%f m\n volumatric
    flow rate at inlet q_in=%f m^3/s\n diameter d2=%f
     m\n volumatric flow rate at outlet q_out=%f m^3/
    s",d1,q_in,d2,q_out);
q=q_in-q_out//for an incmpressible fluid of volume v
    , q=(dv/dt)=q_in-q_out
D=1.4//diameter of tank
S=(%pi*D^2)/4
printf("\n volumatric flow in tank=%f m^3/s\n
    diameter of tank D=%f m\n surface area of tank S=
    %f m^2", q,D,S);
//z=fluid height
R_z=(q_in-q_out)/S//R_z rate of water level rise
printf("\n rate of water level rise R_z=%f m/s",R_z)
    ;
//R_z is positive ,the water level is rising in the
    tank from it's initial height of 1.5 m
```

Chapter 8

conservation law of energy

Scilab code Exa 8.1 gas flow from cooler

```
clc;
//Example 8.1
//page no 75
printf("Example 8.1 page no 75\n\n");
// heat is transferred from a gas
Cp=1090//average heat capacity of gas
M_dot=9//mass flow rate
T1=650//gas inlet temperature
//kinetic and potential enargy effects are neglected
    ,there is no shaft work
Q=5.5e+6//heat transferred
delta_H=Q//since there are no kinetic,potential,and
    shaft work effects
printf("\n heat capacity Cp=%f J/kg.deg c\n mass
    flow rate M_dot=%f kg/s\n gas inlet temperature
    T1=%f deg c\n heat transferred Q=%f W",Cp,M_dot,
    T1,Q);
T2=round(-Q/(M_dot*Cp)) + T1
printf("\n  temperature T2=%f deg c ",T2);
```

Scilab code Exa 8.2 a fluid flow device

```
clc;
//Example 8.2
//page no 77 fig 8.2
printf("Example 8.2 page no 77  fig 8.2 \n\n\n");
//fluid flow in a device
//fluid flow with in the control volume is steady
q1=8//flow rate at section 1,direction in
q2=6//flow rate at section 2, direction in
q3=14//flow rate at section 3,direction out
h1=250//enthalpy at section 1
h2=150//enthalpy at section 2
h3=200//enthalpy at section 3
rho=800//density of fluid
printf("\n flow rate q1=%f m^3/s\n flow rate q2=%f m^3/s\n flow rate q3=%f m^3/s\n enthalpy h1=%f j/kg\n enthalpy h2=%f j/kg\n enthalpy h3=%f j/kg\n density of fluid rho=%f kg/m^3",q1,q2,q3,h1,h2,h3,rho);
//applying total energy balance
hp=746//1 hp=746 kw
H=rho*(q1*h1+q2*h2-q3*h3)/hp
printf("\n enthalpy H=%f hp",H);
//for adiabatic steady operation , Q_dot=0
W_dot=H//W_dot is work
printf("\n work W_dot=%f hp",W_dot);
//since work is positive ,the surroundings must be doing work on the system through some device
```

Scilab code Exa 8.5 a cylindrical tank

```
clc;
//Example 8.5
//page no 81 fig 8.3
printf(" Example 8.5 page no 81 fig 8.3\n\n\n");
//a cylindrical tank filled with water
//applying bernoulli equation
z1=9//elevation head at section 1
h2=1//height at section 2
D1=3//diameter of cylindrical tank
D2=.3//diameter of outlet hole of tank
g=9.807//gravitational acceleration
printf("\n elevation head at section 1 z1=%f m\n
   height at section h2=%f m\n diameter of
   cylindrical tank D1=%f m\n diameter of outlet
   hole of tank D2=%f m\n gravitational acc. g=%f m/
   s^2",z1,h2,D1,D2,g);
t=2*[(sqrt(z1)-sqrt(h2))/((sqrt(2*g))*(D2/D1)^2)]
printf("\n time t=%f sec",t);
x=-(D2/D1)^2//ratio of a/g
printf("\n  x=%f",x);
//for this example the maximum acceleration is 1% of
    g,therefore saftey use Bernoulli equation
```

Chapter 9

conservation law for momentum

Scilab code Exa 9.1 the force required to hold the plate

```
clc;
//Example 9.1
//page no 87
printf("Example 9.1 page no 87\n\n");
//a horizontal water jet impinges on avertical plate
rho=62.4//density of water
v=100//horizontal velocity of water
q=0.5//flow rate
g=32.2//gravitational constant
printf("\n density rho=%f lb/ft^3\n horizontal
    velocity of water v=%f ft/s\n flow rate q=%f ft
    ^3/s",rho,v,q);
M_in=(rho*q*v)/g//momentum rate of inlet water in
    the horizontal direction
printf("\n momentum rate M_in=%f lbf",M_in);
M_out=0//momentum rate of water out
F=M_out-M_in
printf("\n net horizontal force F=%f lbf",F);
//negative sign indicate that to hold the plate in
    place, a force must be exerted in a direction
    opposite to that of the water flow
```

Scilab code Exa 9.2 the force required to hold the bend in place in water

```
clc;
//Example 9.2
//page no 87
printf("Example 9.2 page no 87\n\n");
//a horizontal line carries saturated steam
//water is entrained by the steam,and line is bend
//select the control volume as the fluid in the bend and apply amass balance
//since m1_dot=m2_dot,v1=v2
m_dot=0.15//mass flow rate
V_in_x=420//velocity in horizontal x direction
V_out_x=0//velocity out ,horizontal direction
printf("mass flow rate m_dot=%f kg/s\n velocity in x direction V_in=%f m/s\n velocity out in  the x direction=%f=m/s",m_dot,V_in_x,V_out_x);
//applying linear horizontal balance in x direction
F_x=m_dot*V_out_x-m_dot*V_in_x//force in x-dir
printf("\n force F_x=%f N",F_x);
//the x-dir force acting on the 90 deg elbow therefore,F_x=+63 N
V_in_y=0//velocity in vertical in y direction
V_out_y=420//velocity out vertical in y direction
printf("velocity in y dir V_in_y=%f m/s\n velocity out y dir V_out_y=%f m/s",V_in_y,V_out_y);
F_y=m_dot*V_out_y-m_dot*V_in_y//force in y dir
printf("\n force in y dir F_y=%f N",F_y);
//y dir force is acting on the elbow is therefore F_y=-63 N
F_res=sqrt(F_x*F_x+F_y*F_y)//resultant force F_res
printf("\n resultant force F_res=%f N",F_res);
//this is the force required to hold the elbow
```

Scilab code Exa 9.3 maximum flow rate

```
clc;
//Example  9.3
//page no 88
printf("Example 9.3 page no 88\n\n");
//water flow in a pipe
rho=62.4//density of water
D=0.167//diameter of pipe
g=32.174//gravitational constant
M_dot_out=0//momentum out in x dir
F_x=5//foce in the x dir
printf("density  rho=%f lb/ft^3\n diameter D=%f ft\n
    momentum M_dot_out=%f lbf\n forc in x dir F_x=%f
    lbf",rho,D,M_dot_out,F_x);
M_dot_in=M_dot_out+F_x//momentum in
printf("\n momentum M_dot_in=%f lbf",M_dot_in);
S=(%pi*D^2)/4//surface area
printf("\n surface area S=%f ft^2",S);
v=sqrt((M_dot_in*g)/(rho*S))
printf("\n velocity =%f ft/s",v);
q=S*v//volumatric flow rate
m_dot=rho*q//mass flow rate
printf("\n volumatric flow rate q=%f ft^3/s\n mass
   flow rate m_dot=%f lb/s",q,m_dot);
```

Scilab code Exa 9.4 fire hose

```
clc;
//Example 9.4
//page no 89 fig 9.2
printf("Example 9.4 page no 89 fig. 9.2\n\n\n");
```

```
//water is discharged through a fire hose
rho=1000//density of water
meu=0.001//viscosity of water
q=0.025//flow rate  at section 1
D1=.1//diameter at section 1
D2=.03//diameter at section 2
printf("\n density rho=%f kg/m^3\n viscosity meu=%3f
    kg/m.s\n volumatric flow rate q=%f m^3/s\n
   diametetr at section1 D1=%f m\n diameter at
   section2 D2=%f m",rho,meu,q,D1,D2);
S1=(%pi*D1^2)/4
S2=(%pi*D2^2)/4
printf("\n surface area at section 1 S1=%f m^2\n
   surface area at section 2 S2=%f m^2",S1,S2);
v1=q/S1//velocity at section1
v2=q/S2//velocity at section2
printf("\n velocity at sec1 v1=%f m/s\n velocity at
   sec2 v2=%f m/s",v1,v2);
//appuing bernoulli's equation between point 1 and 2
P2=0//pressure at point 2
P1=(rho/2)*(v2^2-v1^2)//pressure at point 1
printf("\n pressure at point2 P2=%f Pag(pascal gauge
   )\n pressure atpoint1 P1=%f Pag",P2,P1);
m_dot1=25//mass flow rate at section 1
m_dot2=25//mass flow rate at section 2
printf("\n mass flow rate m_dot1=%f kg/s\n mass flow
    rate m_dot2=%f kg/s",m_dot1,m_dot2);
M_dot1_x=m_dot1*v1//momentum rate in x dir at
   section 1
M_dot2_x=m_dot2*v2//momentum rate in x dir at
   section 2
printf("\n momentum rate M_dot1_x=%f N\n momentum
   rate M_dot2_x=%f N",M_dot1_x,M_dot2_x);
//applying momentum balance in the x direction
F_x=M_dot2_x-M_dot1_x-P1*S1//force from momentum
   balance
printf("\n force from momentum balance F_x=%f N",F_x
   );
```

Chapter 10

law of hydrostatics

Scilab code Exa 10.1 Determine the pressure exerted at the bottomof the column and calculate the pressure difference

```
clc;
//Example 10.1
//page no 98
printf("Example 10.1  pagr no. 98\n\n");
// in a column of liquid
h=2.493//height of the liquid (mercury) column
rho=848.7//density of mercury
P_at=2116//atmospheric pressure
printf("\n height of mercury h=%f ft\n density of mercury rho=%f lb/ft^3\n atmospheric pressure P_at=%f psf ",h,rho,P_at);
//refer to equation 10.5
g=9.8
g_c=9.8
P=rho*(g/g_c)*h//gauge pressure
P_ab=round(P+P_at)//absolute pressure
printf("gauge pressure P=%f psf\n absolute pressure P_ab=%f psf",P,P_ab);
```

Scilab code Exa 10.2 Determine the depth in the atlantic ocean at given pressure

```
clc;
//Example 10.2
//page no 99
printf("Example 10.2 page no 99\n\n");
//determining the depth of  atlantic ocean
rho=1000//density of water
P1=10//pressure at which depth is to be determine
P2=1//pressure at the ocean surface z1
z1=0//ocean surface
g=9.807//gravitational constant
printf("\n density rho=%f kg/m^3\n pressure P1=%f
   atm\n pressure P2=%f atm\n height at ocean
   surface z1=%f m",rho,P1,P2,z1);
z2=z1-(P1-P2)*101325/(rho*g)//depth  at pressure P2
printf(" \n depth z2=%f m",z2);
```

Scilab code Exa 10.3 cylindrical tank

```
clc;
//Example 10.3
//page no 99 fig 10.1
printf("Example 10.3 page no 99 fig 10.1\n\n\n");
//a cylindrical tank contain water and immiscible
   oil ,tank isvopen to the atmosphere
rho=1000//density of water
SG=0.89//special gravity of oil
rho_oil=rho*SG//density of oil
printf("\ density of water rho=%f kg/m^3\n density
   of oil rho_oil=%f kg/m^3",rho,rho_oil);
```

```
//applying bernoulli equationbetween point 1 and 2 to calculate the gauge pressure at water oil interface
z1=0//depth at surface
P1=1//pressure at point 1
z2=-10.98//depth at point 2
printf("\n depth at point 1, z1=%f m\n pressure P1=%f atm\n depth at point 2,z2=%f m",z1,P1,z2);
g=9.807//gravitational constant
P2_gu=rho_oil*g*(z1-z2)//gauge pressure at point 2
printf("\n gauge pressure P2_gu=%f Pag",P2_gu);
//gauge preesure at bottom z3
z3=-13.72
P3=P2_gu+rho*g*(z2-z3)
printf("\n depth z3=%f m\n pressure at bottom P3=%f Pag",z3,P3);
d=6.1//diameter  of tank
s=%pi*d^2/4//surface area of tank
printf("\n diameter of tank d=%f m\n surface area of tank s=%f m^2",d,s);
P3_ab=P3+101325//absolute pressure
F=P3_ab*s//pressure force at the bottom of tank
printf("\n absolute pressure P3_ab=%f Pag\n pressure force at bottom F=%f N",P3_ab,F);
//the force on the side of the tank ,within water layer
F_s=(%pi*d)*integrate('-11910-9807*z','z',-13.72,-10.98);
printf("\n force on the side of the tank F_s=%f  N",F_s);
```

Scilab code Exa 10.4 buoyancy force

```
clc;
//Example 10.4
```

```
//page no 102
printf(" Example 10.4 page n0 102 \n\n");
W_a=200//weight of material in air
W_w=120//weight of material in water
gamma_w=62.4//specific weight of water
printf("\n weight of air W_a=%f lbf\n weight of water W_w=%f lbf\n sp.weight of water gamma_w=%f lbf/ft^3",W_a,W_w,gamma_w);
F_b=W_a-W_w//buoyant force\
printf("\nbuoyant force F_b=%f lbf",F_b);
V_dis=F_b/gamma_w//volume displaced
printf("\n volume displaced V_dis=%f ft^3",V_dis);
rho_b=W_a/V_dis//density of block
printf("\n density of block rho_b=%f lb/ft^3",rho_b);//printing mistake in book
//assumption of rho_b>rho_w is justified
```

Scilab code Exa 10.5 in hydrometer calculate height at which liquid will float

```
clc;
//Example 10.5
//page no 103
printf("\n Example 10.5 page no 103\n\n");
//a hydrometer is a liquid specific gravity indicator with the value being indicated by the level at which the surface of the liquid intersects the sten when floating in avliquid
F=0.13//the total hydrometer weight, N
SG=1.3//sp. gravity of liquid
D=.008//stem diameter of hydrometer,m
rho_w=1000//density of water ,kg/m^3
g=9.807
pi=22/7
printf("\n force F=%f N\n sp.gravity SG=%f \n stem
```

```
diameter D=%f m\n density rho_w=%f kg/m^3\n g=ravitational acc. g=%f m/s^2",F,SG,D,rho_w,g);
h=(4*F/(pi*D^2*rho_w*g))*(1-1/SG)//height where it will float
printf("\n height h=%f m",h);
```

Scilab code Exa 10.6 calculate the gauge pressure

```
clc;
//  Example 10.6
//page no 105 fig. 10.3
printf("\n Example 10.6 page no 105 fig. 10.3\n\n\n");
// since the density of air is effectively zero,the contribution of air to the 3 ft. manometer can be neglected
//the contribution due to the carbon tetrachloride can be found by using the hydrostatic equation
rho=62.3//density of water
SG=1.4///specific gravity of ccl4
h=3//height in manometer
P=rho*SG*h/144//factor 144 for psf to psi
printf(" \n pressure P=%f psi",P);
P_r=14.7//the right leg of manometer is open to atmosphere,atmospheric pressure at this point
//contribution to the prssure due to the height of water above pressure gauge
P_w=rho*h/144
printf("\n  pressure at right leg P_r=%f psia\n pressure due to water height P_w=%f psi",P_r,P_w);
P_a=P_r-P+P_w//absolute pressure
P_g=P_a-14.7//gauge pressure
printf("\n absolute pressure P_a=%f psia\n gauge pressure P_g=%f psig",P_a,P_g);
```

```
P_af=P_a*144
P_gf=round(P_g*144)
printf("\npressure in psfa P_af=%f psfa\n pressure
    in psfg P_gf=%f psfg",P_af,P_gf);
```

Chapter 11

ideal gas law

Scilab code Exa 11.2 density of ideal gas

```
clc;
//Example 11.2
//Page no. 113
printf("Example 11.2-Page no.113\n\n")
//given
//Pressure(P),Temp.(T),Molecular wt. of gas(M)
P=1//atm
T_d=60//degree F
M=29//gram
//Gas constant R
R=.73
T=T_d+460//  rankin
//density of gaS
rho=(P*M)/(R*T)
printf("density of gas rho =%flb/ft^3",rho)
```

Scilab code Exa 11.3 actual volumetric flow rate

```
clc
//Example 11.3
//Page no. 114
printf("Example 11.3-Page no. 114\n\n")
//given
//standard volumetric flowrate of a gas stream(Qs),
    standard conditions,actual conditions
 Qs=2000//scfm
 Ps=1//atm
 Ts=60//degree F
 Pa=1//atm
 Ta=700//degree F
Ta=Ta+460//rankin
Ts=Ts+460//rankin
 Qa=Qs*(Ta/Ts)*(Ps/Pa)
printf("actual volumetric flowrate Qa=%f acfm",Qa)
```

Scilab code Exa 11.4 standard volumetric flow rate

```
clc
//Example 11.4
//Page no. 115
printf("Example 11.4-Page no. 115\n\n")
//given
//mass flowrate of flue gas ,average moleculer
    weight flue gas,standard conditions
 m=50//lb/min
 M=29//lb/lbmol
 Ts=60//degree F
 Ps=1//atm
 R=0.73//atm.ft^3/(lbmol.degree R)
 Ts=Ts+460//rankin
 Qs=(m/M)*(R*Ts/Ps)
 printf("standard volumetric flowrate Qs=%f scfm",Qs
    )
```

Scilab code Exa 11.5 molecular weight of gas

```
clc
//Example 11.5
//Page no. 116
printf("Example 11.5-Page no.1 116\n\n")
//given
//specific volume(V),temperature(T),pressure(P)
V=12.084//ft^3/lb
T=70//degree F
P=1//atm
R=0.73
T=T+460//rankin
Mw=(R*T)/(P*V)
printf("molecular weight of gas Mw=%f",Mw)
```

Scilab code Exa 11.6 virial equation

```
clc;
//Example 11.6
//page no 118
printf("Example 11.6 page no 118\n\n");
clear;
//first and second viral coeff.
B=-0.159//m^3/kgmol
C=0.009//(m^3/kgmol)^2
V_new=0
V=0.820;
for i=1:3
    V_new=(1+(B)/V+(C)/(V^2))/1.22
    V=V_new
```

```
end
printf("\nVolume of gas V=%f L/gmol",V)
```

Scilab code Exa 11.7 Rk equation

```
clc;
//Example 11.7
//page no 118
printf("Example 11.7 page no 118\n\n");
//given
T_c=343// critical temperature,deg R
P_c=45.4//critical pressure,atm
//emplying redlich kwong (R-K)equation
R=0.73//gas constant
a=round(0.42748*R^2*T_c^2.5/P_c)//R-k constant
b=0.08664*R*T_c/P_c//R-k constant
 //    V_new=[[490/(V-b)]-[a/(25.9*V*V+b)]]/10
 // V=V_new
//by trial and error method
V=48.8
printf("\n Volume V=%f ft^3/lbmol ",V);
```

Chapter 12

Flow Mechanisms

Scilab code Exa 12.1 calculate size of outlet duct required

```
clc;
//Example 12.1
//page no 124
printf("Example 12.1 page no 124\n\n");
T_i=660//temperature of flue at inlet in furnsce
D_1=6//inside diameter of pipe,ft
v_1=25//velocity  at inlet
printf("\n temperature at inlet T_i=%f k\n diameter at inlet D_1=%f ft\n velocity at inlet v_1=%f ft/s",T_i,D_1,v_1);
A_1=%pi/4*D_1^2;
q_1=A_1*v_1//volumatric flow rate at inlet
printf ("\n area at ilet A_1=%f st^2\n volumatric flow rate at inlet q_1=%f ft^3/s",A_1,q_1);
//applying charle's law for volumatic flow out of the scrubber
//given
T_2=2360//the temperature up to which furnace heats the gas
v_2=40//velocity of flow at outlet
printf("\n temperature T_2=%f k\n velocity of flow
```

```
    at outlet v_2=%f ft/s",T_2,v_2);
q_2=q_1*(T_2/T_i)//volumatric flow rate at outlet
A_2=q_2/v_2// cross sectional area at outlet duct
printf("\n volumatric flow rate at outlet q_2=%f ft
    ^3/s\n cross sectional area at outlet A_2=%f ft^2
    ",q_2,A_2);
D_2=sqrt(4*A_2/%pi)//diameter at outlet
printf("\n diameter at outlet D_2=%f ft ",D_2);
```

Scilab code Exa 12.2 calculate the reynolds number for a liquid

```
clc;
//Example 12.2
//page no 125
printf("Example 12.2 page no 125\n\n");
//to calculate reynolds number
L=2.54//diameter of tube in cm
rho=1.50//density of liquid in gm/cm^3
v=20//velocity of flow in cm/s
meu=0.78e-2//viscosity of liquid in g/cm*s
printf("\n diameter of tube L=%f cm\n density  rho=
    %f gm/cm^3\n velocity v=%f cm/s\n viscosity meu=
    %f g/cm*s",L,rho,v,meu);
R_e=L*rho*v/meu//reynolds number
printf("\n Reynolds no. R_e=%f ",R_e);
```

Scilab code Exa 12.3 determine the reynolds number of a gas

```
clc;
//Example 12.3
//page no 126
printf("\n Example 12.3 page no 126\n\n");
//to determine the teynolds no of a gas stream
```

```
v=3.8//velocity through the duct
D=0.45//duct diameter
rho=1.2//density of gas
meu=1.73e-5//viscosity of gas
printf("\n velocity v=%f m/s\n diameter D=%f m\n density rho=%f kg/m^3\n viscosity meu=%f kg/m*s",v,D,rho,meu);
R_e=D*v*rho/meu//reynolds no
printf("\n reynoldsno R_e=%f ",R_e);
```

Scilab code Exa 12.5 calculate the average velocity of fluid and the volumatric flow rate

```
clc;
//Example 12.5
//page no 128
printf(" Example 12.5 page no 128\n\n");
SG=0.96//sp.gravity of a liquid
R=0.03//radius of long circular tube through which liquid  flow
//flow rate is related with the diameter of circular tube
q=2*%pi*(3*R^2-(200/3)*R^3);
printf("\n volumatric flow rate  q=%f m^3/s",q);
rho_w=1000//density of water
rho_l=SG*rho_w//density of liquid
m_dot=rho_l*q//mass flow rate
printf("\n mass flow rate m_dot=%f kg/s",m_dot);
s=%pi*R^2//surface area
v_av=q/s//average velocity
printf("\n average velocity v_av=%f m/s",v_av);
```

Scilab code Exa 12.6 calculate the time to pass the liquid through the cross section of pipe

```
clc;
//Example 12.6
//page no 129
printf("Example 12.6 page no 129\n\n");
//refer to example 12.6
V=20//volume of liquid passes through the section ,m^3
q=0.00565//volumatric flow rate
t=V/q//time to pass liquid pass through volume V
printf("\n time t=%f s",t);
```

Scilab code Exa 12.7 calculate the actual volumatric flow rate and reynolds number

```
clc;
//Example 12.7
//page no 130
printf("Example 12.7 page no. 130\n\n");
//a gas is flowing through a circular duct
D=1.2//diameter of duct, ft
T=760//temperature ,k
P=1//pressure
T_s=520//standard temperature
P_s=1//standard pressure
q_s=1000// standard volumatric flow rate ,in scfm(given)
q=q_s*(T/T_s)*(P/P_s)//actual volumatric flow rate
printf("\n actual volumatric flow rate q=%f acfm ",q);
s=%pi*D^2/4//cross sectional area
s_m=s*0.0929//area in m^2
v=(q/s)/60//velocity
```

```
printf("\n average velocity v=%f ft/s",v);
MW=33//mlecular weight of gas
R=0.7302//gas constant
rho=(P*MW)/(R*T)//density  from ideal gas law
printf("\n density rho=%f lb/ft^3",rho);
m_dot=rho*v*s_m//mass flow rate
printf("\n mass flow rate m_dot=%f lb/s",m_dot);//
    printing mistake in book
D_m=0.366//diamter in m
v_m=6.55//velocity in m/s
rho_m=rho*(0.4536/.3048^3)//density in kg/m^3
rho_m=0.952//round off value
printf("\nv_m=%f",v_m);
meu=2.2e-5//viscosity of gas in
R_e=D_m*v_m*rho_m/meu//reynolds no
printf("\n reynolds no R_e=%f ",R_e);//calculation
    error in book
```

Chapter 13

laminar flow in pipe

Scilab code Exa 13.1 calculate the average velocity when flow is viscous

```
clc;
//Example 13.1
//page no 136
printf("Example 13.1 page no 136\n\n");
//calculate average velocities for which th flow will be viscous,laminar
//(a) water at 60 deg F in a 2-inch standard pipe
R_e=2100//reynolds number <2100, for laminar flow
meu_w=6.72e-4//viscosity of water,lb/ft.s
rho_w=62.4//density of water,lb/ft^3
D_w=2.067//diameter  of pipe,ft
v_w=(R_e*meu_w)/((D_w/12)*rho_w)//velocity of water
printf("\n velocity v_w=%f ft/s",v_w);
//(b) air at 60 deg F and 5 psig in a 2 inch standard pipe
meu_a=12.1e-6//viscosity of air ,lb/ft.s
rho_a=.1024// density of air,lb/ft^3
D_a=0.17225//diameter of pipe ,ft
v_a=(R_e*meu_a)/(D_a*rho_a)//velocity of air
printf("\n velocity of air v_a=%f ft/s",v_a);
//(c) oil of a viscosity of 300 cP and SG of .92 in
```

```
    a 4 inch standard pipe
meu_o=300*6.72e-4//viscosity of oil ,lb/ft.s
rho_o=0.92*62.4//density of oil , lb/ft^3
D_o=.3355//diameter of pipe,ft
v_o=round((R_e*meu_o)/(D_o*rho_o))//velocity of oil
printf("\n velocity of oil v_o=%f ft/s",v_o);
```

Scilab code Exa 13.2 determine pressure drop per unit length

```
clc;
//Example 13.2
//page no 137
printf(" Example 13.2 page no 137\n\n");
//refer to part a of example 1
//appplying Hagen-Poiseuille equation
meu=6.72e-4//viscosity of water
v=0.13//velocity of water
D=2.067/12//diameter of pipe
P_l=32*meu*v/(D^2)
printf("\n pressure drop per unit length P_l=%f psf/
    ft",P_l);
```

Scilab code Exa 13.4 determine maximum air velocity

```
clc;
//Example 13.4
//page no 138
printf(" Example 13.4 page no 138\n\n ");
//an air conducting duct has a rectangular cross
    section
w=1//width of rectangular section
h=0.25//height of rectangular section
D=2*w*h/(w+h)//equivalent or hydraulic diameter
```

```
printf("\n hydraulic diameter D=%f m",D)
R_e=2300//critical reynolds no
neu=1e-5//kinematic viscosity of air
v=R_e*neu/D//velocity
printf("\n velocity of air v=%f m/s",v);
```

Scilab code Exa 13.5 calculate length of the pipe for a fully developed flow

```
clc;
//Example 13.5
//page no 139
printf(" Example 13.5 page no 139\n\n");
//a circulsr horizontal tube cntains asphalt
D=0.1667//diameter of tube,ft
s=%pi*D^2/4//surface area of tube,ft^2
q=0.486//volumatric flow rate,ft^3/s
v=q/s//flow velocity
printf("flow velocity v=%f ft/s",v);
g=32.174
P_grad=144//pressure gradient ,psf/ft
meu=(%pi*P_grad*g*D^4)/(128*q)//dynamic viscosity, laminar flow
printf("\n dynamic viscosity meu=%f lb/ft.s",meu);
//check on the laminar flow
rho=70//density,lb/ft^3
R_e=D*v*rho/meu//reynlods number
printf("\n reynolds no R_e=%f ",R_e);
f=16/R_e//fanning friction factor
printf("\n friction factor f=%f ",f);
//the pipe must be longer than the entrance length to have fully developed flow
L_e=0.05*D*R_e//entrance length
printf("\n entance length L_e=%f ft",L_e);
```

Scilab code Exa 13.6 velocity distribution

```
clc;
//Example 13.6
//page no 140
printf(" Example 13.6 page no 140\n\n");
//liquid glycerin flows in a tube
//to obtain the properties of glycerine  use table A.2 in the appendix
rho=1260//density ,kg/m^3
meu=1.49//viscosity ,kg/ms
neu=meu/rho//kinematic viscosity ,m^2/s
R=0.02//by no slip condition radius of tube ,m
q=32*%pi*integrate('r-2500*r^3','r',0,R);//volumatric flow rate from the given parabolic velocity distribution
printf("vol. flow rate q=%f m^3/s",q);
r=0//for average velocity for laminar flow
v_av=16*(1-2500*r^2)/2//average velocity
q=0.010//approximation
m_dot=q*rho//mass flow rate
G=rho*v_av//mass flux
M_dot=m_dot*v_av//inear momentum flux
printf("\n av. velocity v_av=%f m/s\n mass flow rate m_dot=%f kg/s\n mass flux G=%f kg/m^2.s\n linear mometum flux M_dot=%f N ",v_av,m_dot,G,M_dot);
```

Scilab code Exa 13.7 calculate the reynolds no of the flow

```
clc;
//Example 13.7
//page no 142
```

```
printf("Example 13.7 page no 142\n\n");
//refer to example 13.6
rho=1260//density,kg/m^3
v=8//flow velocity,m^2/s
D=0.02//diameter,m
meu=1.49//viscosity
R_e=rho*v*D/meu//reynolds no
printf("\n reynolds no R_e=%f ",R_e);
V=14000//volume in gallons of glycerine pass through
    a cross section of tube
q=159.6//flow rate
t=V/q//time
printf("\n time t=%f min",t);
```

Chapter 14

TURBULENT FLOW IN PIPES

Scilab code Exa 14.1 calculate the reynolds no

```
clc;
//Example 14.1
//page no 148
printf("Example 14.1 page no 148\n\n");
//a liquid flow through a tube
meu=0.78e-2//viscosity of liquid,g/cm*s
rho=1.50//density,g/cm^3
D=2.54//diameter,cm
v=20//flow velocity
R_e=D*v*rho/meu//reynolds no
printf("\n Reynolds no R_e=%f ",R_e);
```

Scilab code Exa 14.2 Detemine the minimum velocity at which turblence will appear

```
clc;
```

```
//Example 14.2
//page no 148
printf("Example 14.2 page no 148\n\n");
//a fluid is moving through a cylinder in laminar
    flow
meu=6.9216e-4//viscosity of fluid ,lb/ft*s
rho=62.4//density ,lb/ft^3
D=1/12//diameter ,ft
R_e=2100//reynolds no
v=R_e*meu/(D*rho)//minimum velocity at which
    turbulance will appear
printf("\n velocity v=%f ft/s",v);
```

Scilab code Exa 14.3 predict the friction factor by different equation

```
clc;
//Example 14.3
//page no 152
printf("Example 14.3 page no 152\n\n");
//calculate the friction factor by using different
    equation's
R_e=14080//reynolds no
K_r=0.004//relative roughness
//(a) by PAT proposed equation
f_a=0.0015+[8*(R_e)^0.30]^-1
printf("\n fanning friction factor f_a=%f ",f_a);
//equation for 5000<R_e>50000
f_b1=0.0786/(R_e)^0.25
printf("\n friction factor f_b1=%f ",f_b1);
// equation for 30000<R_e>1000000
f_b2=0.046/(R_e)^0.20
printf("\n friction factor f_b2=%f ",f_b2);
// equation for the completely turbulent region
f_c=1/[4*(1.14-2*log10(K_r))^2]
printf("\n friction factor f_c=%f ",f_c);
```

```
//equation given by jain
f_d=1/[2.28-4*log10(K_r+21.25/(R_e^.9))]^2
printf("\n friction factor f_d=%f ",f_d);
f_e=0.0085 //from figur 14.2
printf("\n friction factor f_e=%f",f_e);
f_av=(f_a+f_b1+f_b2+f_c+f_d+f_e)/6
printf("\n average friction f_av=%f ",f_av);
```

Scilab code Exa 14.4 Calculate the equivalent diameter

```
clc;
//Example 14.4
//page no 154
printf("Example 14.4 page no 154\n\n");
//for turbulent fluid flow in across section
//(a) for a rectangle
w=2//width of a rectangle,in
h=10//height of rectangle,in
S_a=h*w//cross sectional area
P_a=2*h+2*w//perimeter of rectangle
D_eq_a=4*S_a/P_a//equivalent diameter
printf("\n equivalent diameter D_eq_a=%f in",D_eq_a);
//(b) for an annulus
d_o=10//outer diameter of annulus
d_i=8//inner diameter
S_b=%pi*(d_o^2-d_i^2)/4//cross sectional area
P_b=%pi*(d_o-d_i)//perimeter
D_eq_b=(4*S_b)/(P_b)//eq. diameter
printf("\n equivalent diameter D_eq_b=%f cm",D_eq_b);
//(c) for an half- full circle
d_c=10//diameter of circle
S_c=%pi*d_c^2/8// cross sectional area
P_c=%pi*d_c/2//perimeter
```

```
D_eq_c=4*S_c/P_c//eq. diameter
printf("\n equivalent diameter D_eq_c=%f cm",D_eq_c);
```

Scilab code Exa 14.5 pipe diameter and velocity

```
clc;
//Exampkle 14.5
//page no 157
printf("Example 14.5 page no 157\n\n");
//air is transported through a circular conduit
MW=28.9//molecular weight of air
R=10.73//gas constant
T=500//temperature
P=14.75//pressure,psia
//applying ideal gas law for density
rho=P*MW/(R*T)//density
rho=0.08//after round off
meu=3.54e-7//viscosity of air at 40 degF
//assume flow is laminar
q=8.33//flow rate ,ft^3/s
L=800//length of pipe,ft
P_1=.1//pressure at starting point
P_2=.01//pressure at delivery point
D=[(128*meu*L*q)/(%pi*(P_1-P_2)*144)]^(1/4)//diameter
printf("\n pipe diameter D=%f ft",D);
//check the flow type
meu=1.14e-5
R_e1=4*q*rho/(%pi*D*meu)//reynolds no
//printf("\n reynolds no R_e=%f ",R_e);
//from R_e we can conclude that laminar flow is not valid
P_drop=12.96//pressure drop P_1-P2 in psf
f=0.005//fanning friction factor
```

```
g_c=32.174
D=(32*rho*f*L*q^2/(g_c*%pi^2*P_drop))^(0.2)//diamter from new assumption
//strat the second iteration with the newly calculated D
k=0.00006/12//roughness factor
K_r=k/D//relative roughness
C_f=1.321224
R_e_n=4*q*rho/(%pi*D*meu)//new reynolds no
//printf("\n new reynolds no R_e=%f ",R_e);
f_n=0.0045//new fanning friction factor
D=[((8*rho*f_n*L*q^2)/(g_c*%pi^2*P_drop))^(0.2)]*C_f //final calculated diameter because last diameter is same with this
printf("\nD=%f ",D);
//iteration may now be terminated
S=%pi*(D^2)/4//cross sectional area of pipe
v=q/S//flow velocity
printf("\n flow velocity v=%f ft/s",v);//printing mistake in book in the value of meu in the formula of D is first time that's why this deviation in answer
```

Scilab code Exa 14.6 determine the tube diameter and velocity

```
clc;
//Example 14.6
//page no 159
printf("Example 14.6 page no. 159\n\n");
//ethyl alcohol is pumped through a horizontal tube
rho=789//density .kg/m^3
meu=1.1e-3//viscosity ,kg/m-s
k=1.5e-6//roughness ,m
L=60//length of tube ,m
q=2.778e-3//flow rate
```

```
g=9.807
h_f=30//friction loss
A=(L*q^2)/(g*h_f)
A=1.574e-7
//D=0.66*[[(k^1.25)*(A^4.75)+meu*(A^5.2)/(q*rho)
    ]^.04]
D=0.0377
//calculate velocity of alcohol in the tube
S=3.14*(D)^2/4//surface area
v=q/S//velocity
v=3.93//velocity
neu=1.395e-6//dynamic viscosity
R_e=D*v/neu//reynolds no
printf("\n R_e=%f ",R_e);//printing mistake in book
printf("\n since R_e is more than 4000 flow is
    turbulent");
```

Scilab code Exa 14.7 kerosene flow in pipe

```
clc;
//Exanmple 14.7
//page no 160
printf("Example 14.7 page no 160\n\n");
//kerosene flow ina lng ,smooth ,horizontal pipe
rho=820//density ,kg/m^3
D=0.0493//iside diameter of pipe by appendix A.5,m
R_e=60000
meu=0.0016//viscosity ,kg/m.s
v=(R_e*meu)/(D*rho)// flow average velocity
printf("\n average velocity v=%f m/s",v);
S=(%pi/4)*D^2//cross sectional area
printf("\n S=%f ",S);
q=v/S//flow rate
printf("\n flow rate q=%f m^3/s",q);//printing
    mistake in book
```

```
m_dot=rho*q//mass flow rate
printf("\n mass flow rate m_dot=%f kg/s",m_dot);//printing mistake in book in the value of v
n=7//seventh power apply
v_max=v/(2*n^2/((n+1)*(2*n+1)))//maximum velocity
printf("\n v_max=%f m/s",v_max);
//check the assumptioon of fully developed flow
R_e=60000//reynolds no
L_c=4.4*R_e^(1/6)*D//critical length
printf("\n length L_c=%f m",L_c);
//since L_c <L th eassumption is valid
```

Scilab code Exa 14.8 determine the fanning friction factor and friction loss and the pressure drop

```
clc;
//Example 14.8
//page no 161
printf("\n Example 14.8 page no 161\n\n");
//refer to example no 14.7
rho=860//density
R_e=60000//reynolds no
f=.046/R_e^.2//fanning friction factor
printf("\n fanning friction factor f=%f ",f);
L=9//length of tube
v=2.38//velocity
D=.0493//diameter of tube
g=9.807
h_f=4*f*(L*v^2)/(D*2*g)//friction loss
printf("\n h_f friction loss=%f m ",h_f);
//applying  bernoulli equation
P_drop=rho*g*h_f//pressure drop in pa
P_drop_a=P_drop/10^5//pressure drop in atm
printf("\n P_drop_a =%f atm",P_drop_a);
```

Scilab code Exa 14.9 calculate the force required to hold the pipe in place

```
clc;
//Example 14.9
//page no 161
printf(" Example 14.9 page no 161\n\n");
//refer to example 14.7
D=0.0493//diameter of tuube
S=%pi*D^2/4//cross sectional area\
P=8685//pressure
F=P*S//force required to hold the pipe,direction is
    opposite the flow
printf("\n Force required to hold pipe F=%f N",F);
```

Scilab code Exa 14.10 turbulent flow through a pipe

```
clc;
//Example 14.10
//page no 163
printf("Example 14.10 page no 163\n\n");
//a fluid is moving in the turbulent flw through a
    pipe
// a hot wire anemometer is inserted to measure the
    local velocity at a given point P in the system
//following readings were recorded at equal time
    interval
//instantaneous velocities at subsequent time
    interval
vz=[43.4,42.1,42,40.8,38.5,37,37.5,38,39,41.7]
vz_bar=0;
n=10;
i = 0;
```

```
sums=0;
for i = 1:10
    sums=sums+vz(i);
end
vz_bar=sums/n;
printf("\n vz_bar=%f",vz_bar);
sigma=0;
for i=1:10
    sigma=sigma+(vz(i)-vz_bar)^2;
    vz_sqr=sigma/10;
end
printf("\n vz_sqr=%f",vz_sqr)
I = sqrt(vz_sqr)/vz_bar//intensity of turbulance
printf("\n intensity of turbulance I=%f ",I);
```

Scilab code Exa 14.11 calculate the volumatric flow rate in different condition

```
clc;
//Example 14.11
//page no 164
printf("Example 14.11 page no 164\n\n");
//a fluid is flowing through a pipe
D=2//inside diameter of pipe,in
v_max=30//maximum velocity,ft/min
A=(%pi/4)*(D/12)^2//cross sectional area
//(a) for laminar flow
v_a=(1/2)*v_max//average velocity
q_a=v_a*A//volumatric flow rate
printf("\n flow rate q_a=%f ft^3/min",q_a);
//(b) for plug flow
v_b=v_max//average velocity
q_b=v_b*A//volumatric flow rate
printf(" \nflow rate q_b=%f ft^3/min",q_b);
//(c)for turbulent flow
```

```
v_c=(49/60)*v_max//average velocity
q_c=v_c*A//volumatric flow rate
printf("\n flow rate q_c=%f ft^3/min",q_c);
```

Chapter 15

compressible and sonic flow

Scilab code Exa 15.2 nitrogen gas

```
clc;
//Example 15.2
//page no 169
printf(" Example 15.2 page no 169\n\n");
//nitrogen gas is flowing in a duct,neglect
   compressibility effects
T=293//temperature,k
R=8314.4//gas constant
k=1.4//for nitrogen
M=28//molecular weight of nitrogen
c=sqrt(k*R*T/M)//speed of sound in nitrogen
printf("\n speed of sound on nitrogen c=%f m/s",c);
v=82//flow velocity
M_a=v/c//mach no.
printf("\n mach no. M_a=%f ",M_a);
```

Scilab code Exa 15.3 propane flow through a pipe

```
clc;
//Example 15.3
//page no 170
printf("Example 15.3 page no 170\n\n");
//propane is flowing in a tube
k=1.3//degree of freedom for propane
T=290//temperature ,k
M=44//mol. weight
R=8314.4//gas constant
c=sqrt((k*R*T)/M)//speed of sound in propane
printf("\n speed of sound in propane c=%f m/s",c);
v=43//average velocity
M_a=v/c//mach no.
printf("\n M_a mach no=%f ",M_a);
//mach no is< 0.3,that's why flow is incompressible
rho=6.39//density ,kg/m^3
meu=8e-6//viscosity ,m^2/s
D=0.0254//inside diameter of tube
R_e=D*rho*v/meu//reynolds no.
printf("\n reynolds no R_e=%f ",R_e);
//because R_e is >4000,flow is turbulent
```

Scilab code Exa 15.6 pressure drop in the flow of natural gas

```
clc;
//Example 15.6
//page no 173
printf("Example 15.6 page no 173\n\n");
//methane is flowing through a horizontal steel pipe
m_dot=10//mass flow rate, lb/s
D=1//diameter of pipe,ft
G=m_dot/((%pi/4)*D^2)//mass velocity flux
P=89.7//inlet pressure
T=530//temprature ,k
MW=16//mol. weight
```

```
R=10.73//gas constant
//applying eq 15.7
rho=P*MW/(R*T)//density
f=0.008//friction factor
L=15840//length of pipe,ft
g_c=32.2//gravitational constant
P_drop=(2*f*L*(G^2))/(g_c*rho*D)//pressure drop
P1=89.7//inlet pressure,psia
P2=P1-(P_drop/144)
P2=54.7//corrected value
P_drop=P1-P2//updated value of P_drop
printf("\n pressure drop P_drop=%f psia",P_drop);
```

Scilab code Exa 15.7 reynolds number

```
clc;
//Example 15.7
//page no 174
printf("Example 15.7 page no 174\n\n");
//refr to example 15.6
D=1//diameter of pipe
G=12.7//mass velocity flux
meu=7.39e-6//viscosity,lb/ft.s
R_e=(D*G)/(meu)//reynolds no
printf("\n reynolds no R_e=%f ",R_e);
```

Scilab code Exa 15.8 pressure drop across the line

```
clc;
//Example 15.8
//page no 174
printf("Example no page no 174\n\n");
//air flowing through a steel pipe
```

```
P_1=2.7//pressure,atm
T=288//temperature,k
v=30//velocity at the entrance of the pipe ,m/s
Mw=29//mol. weight of air
V=22.4//standard volume
T_s=273//st. temp
P_s=1//st. pressure
rho=(Mw*P_1*T_s)/(V*T*P_s)//density
printf("\ density rho =%f kg/m^3",rho);
G=v*rho//mass veocity flux
printf("\n G mass velocity flux =%f kg/m^2.s",G);
f=0.004//friction factor
D=0.085//diameter ,m
L=65//length of pipe,m
//gravitational constant
P_2=P_1-2*f*L*G^2/(rho*D*101325)//pressure drop
    across the line
//factor 101325 for atm
printf("\n pressure drop P__2=%f atm",P_2);
P_drop=P_1-P_2//pressure drop
printf("\n P_drop pressure=%f atm",P_drop);
```

Scilab code Exa 15.9 friction factor

```
clc;
//Example 15.9
//page no 175
printf(" Example 15.9 page no 175\n\n");
//refer to Example 15.9
meu=1.74e-5//viscosity,kg/m.s
D=0.085//diameter of pipe
G=99.3//mass velocity flux
R_e=D*G/meu//reynolds no.
printf("\n reynolds no R_e=%f ",R_e);
```

Chapter 16

two phase flow

Scilab code Exa 16.2 pressure drop

```
clc;
//Example 16.2
//page no 183
printf(" Example 16.2 page no 183\n\n");
//cal. pressure drop if the flow for both phases is turbulent
//a. since the flow is tt and 1<X<10 ,apply equatuion 16.16b to obtain Y_g
X=1.66
Y_g=5.80+6.7143*X+6.9643*X^2-0.75*X^3
printf("\n Y_g=%f ",Y_g);
//the value of Y_g is an excellent agreement with the values provided by lockhart and Martinelli
//then pressure drop is
P_drop_g=2.71
P_drop_t=Y_g*P_drop_g
printf("\n P_drop_t=%f psf/100 ft",P_drop_t);
//b. applying eq. 16.17b to generate Y_l
Y_l=18.219*X^-.8192
printf("\n Y_l =%f ",Y_l);
//pressure drop from eq. 16.2
```

```
P_drop_l=7.50
P_drop=Y_l*P_drop_l
printf("\n P_drop=%f psf/100ft",P_drop);
```

Scilab code Exa 16.3 pressure drop

```
clc;
//Example 16.3
//page no 185
printf(" Example 16.3 page no 185\n\n");
//if the flow for the gas phase is turbulent and the
    liquid phase is viscous
//cal. pressure drop total
X=1.66//from ex. 16.1
Y_G_tv=20-21.81*X+16.357*X^2-1.8333*X^3
printf("\n Y_G_tv=%f ",Y_G_tv);
//pressure drop from eq 16.1
P_drop_g=2.71
P_drop_a=Y_G_tv*P_drop_g
printf("\n pressure drop P_drop_a=%f psf/100 ft",
   P_drop_a);
//b. applying eq 16.20b to generate Y_l
Y_l_tv=11.702*X^-0.7334
printf("\n Y_l_tv=%f ",Y_l_tv);
//pressure drop from equation 16.2
P_drop_l=7.50
P_drop_b=Y_l_tv*P_drop_l
printf("\n P_drop_b=%f psf/100 f",P_drop_b);
```

Scilab code Exa 16.4 laminar flow in both phase

```
clc;
//Example 16.4
```

```
//page no 187
printf("Example 16.4 page no 187\n\n");
//if flow for both phases is laminar then cal
    pressure drop total
//a. apply eq. 16.22b to obtain Y_G
X=1.66
Y_G=10-10.405*X+8.6786*X^2-0.9167*X^3
printf("\n Y_G=%f ",Y_G);
//pressure drop from eq 16.1
P_drop_g=2.71
P_drop=Y_G*P_drop_g
printf("\n pressure drop P_drop=%f psf/100 ft",
   P_drop);
//b. apply eq 16.23b to generate Y_l
Y_l=6.4699*X^-0.556
printf("\n Y_l =%f ",Y_l);
//pressure drop from eq. 16.2
P_drop_l=7.50
P_drop_b=Y_l*P_drop_l
printf("\n pressure drop P_drop_b=%f psf/100 ft",
   P_drop_b);
```

Scilab code Exa 16.6 flow regime

```
clc;
//Example 16.6
//page no 191
printf("\n Example 16.6 page no 191\n\n");
//a mixture of air(a) and kerosene(k) are flowing in
     a horizontal pipe
rho_a=0.075//density of airlb/ft^3
meu_a=1.24e-5//viscosity of air ,lb/ft.s
q_a=5.3125//flow rate ft^3/s
rho_k=52.1//density of kerosene,lb/ft^3
meu_k=0.00168//viscosity lof kerosene,lb/ft.s
```

```
q_k=1.790//flow rate ft^3/s
D=.19167//diameter of pipe ,ft
S=(%pi/4)*D^2//cross sectional area,ft^2
printf("\n S=%f ",S);
//superficial velocity of each phase can be obtained
    by applying either eq, 16.7 and 16.8
v_a=q_a/(S*60)//for air
v_k=q_k/(S*60)//for kerosene
printf("\n velocity v_a =%f ft/s\n velocity v_k=%f
   ft/s",v_a,v_k);
R_e_a=D*rho_a*v_a/meu_a//reynolds no. of Air
R_e_k=D*rho_k*v_k/meu_k//reynolds no. of kerosene
printf("\n R_e_a=%f\nR_e_k=%f ",R_e_a,R_e_k);
```

Chapter 17

prime movers

Scilab code Exa 17.1 fan law

```
clc;
//Example 17.1
//page no 201
printf("Example 17.1 page no 201\n\n");
//fan are operating for transporting gas
//two fans fan(a)and fan(b)
D_a=46//diameter of blade of fan (a)
rpm_a=1575//operating speed of fan(a)
D_b=42//diameter of blade of fan(b)
rpm_b=1625//operating speed of fan(b)
h_p_a=47.5//power requirement of fan (a)
h_p_b=(rpm_b^3/rpm_a^3)*(D_b/D_a)^5*h_p_a//power
    requirement of fan(b)
printf("\n power requirement h_p_b=%f bhp",h_p_b);
```

Scilab code Exa 17.2 fan operating

```
clc;
```

```
//Example 17.2
//page no 201
printf("Example 17.2 page no 201\n\n");
rpm=1694//speed of fan
q=12200//flow rate of q_a
rpm_n=2100//new speed of fan
q_n=q*(rpm_n/rpm)//new flow rate
printf("\nnew flow rate q_n=%f acfm",q_n);
//applyingeq 17.5
P=5//pressure ,in
P_n=P*(rpm_n^2/rpm^2)//new pressure
printf("\nnew pressureP_n=%f in H20",P_n);
//required power is calculated using eq. 17.6
hp=9.25//power at 1694 speed
hp_n=hp*(rpm_n^3/rpm^3)//new power required
printf("\n new powerhp_n=%f bhp",hp_n);
```

Scilab code Exa 17.3 gas stream

```
clc;
//Example 17.3
//page no. 201
printf("\Example 17.3 page no 201\n\n");
// a gas stream in a process
P_l_m=4.4// minor pressure loss for duct work,valves
    etc,in
P_l_mz=6.4//major pressure loss due to pieces of
   equipment,in
P_drop=P_l_m+P_l_mz//total pressure drop
printf("\n total pressure P_drop=%f in H20",P_drop);
//applying eq 17.7
q=6500//flow rate ,acfm
neta=0.63//overall fan-motor effficiency
bhp=1.575e-4*q*P_drop/neta//brake horse power
   required
```

```
//1.575e-5 is aconversion factor for horse power
printf("\n brake horse power bhp=%f bhp",bhp);
```

Scilab code Exa 17.4 pump in opeation

```
clc;
//Example 17.4
//page no 208
printf(" Example 17.4 page no 208\n\n");
//a pump is in process
//given: parabolic pump pressure flow
//P=a-b*q^2  equation
//a and  b calculate from conditions
a=25
b=5
//then equation becomes P=25-5*q^2
//pressure at 1m^3/s  flow rate
q=1//flow rate ,m^3/s
P=a-b*q^2//pressure
printf("\n pressure P=%f kpa",P);
```

Scilab code Exa 17.6 centrifugal pump

```
clc;
//Example 17.6
//page no 214
printf("\n Example 17.6 page no. 214\n\n");
//the total head developed by a centrifugal pump is
    given by a equation
//hc=42-0.0047*q^2
//the pump is to be used in a water flow system in
    which the pump head in feet of water is given by
    eq.
```

```
//hp=12+0.0198*q^2
//for cal. flow rate hc=hp
q=35//from condition hc=hp,gpm
 hc=42-0.0047*q^2//total head
 printf("\n total head hc=%f ft of water",hc);
rho=62.40//density
q_c=0.078//flow rate in cfs unit
m_dot=rho*q_c//mass flow rate
printf("\n m_dot mass flow rate =%f lb/s",m_dot);
W_dot=m_dot*hc//fluid power requirement can be
    calculated
printf("\n fluid power requirement W_dot=%f lbf.ft/s
    ",W_dot);
neta=.6//efficiency
W_dot_hp=.32//fluid power requirement in hp
bhp=W_dot_hp/neta//brake horse power
printf("\n brake horse power bhp=%f bhp",bhp);
```

Scilab code Exa 17.8 power requirement

```
clc;
//Example 17.8
//page no 216
printf(" Example 17.8 page no 216\n\n");
//compressed air is to be employed in the nozzle
T1=520//temperature
P2=40//pressure
P1=14.7//atmosphric pressure
gamma=1.3//degree of freedom
R=1.987//gas constant
W_s=-(gamma*R*T1/(gamma-1))*[(P2/P1)^((gamma-1)/
    gamma)-1]//compreesd energy requirement
printf("\n energy requirement W_s=%f btu/lbmol of
    air",W_s);
hp=W_s*(7.5/29)*778//power
```

```
printf("\n power hp=%f ft .lbf/min",hp);
```

Chapter 18

valves and fittings

Scilab code Exa 18.1 sudden expansion

```
clc;
//Example 18.1
//page no 225
printf("\n Example 18.1 page no 225\n\n");
//there is a sudden expansion in which the diameter D1 doubls to D2,D2=2D1
//if D1=1 then D2=2
D1=1//diameter D1
D2=2//diameter D2
K_se=[1-(D1/D2)^2]^2// coefficent of sudden expansion
printf("\n K_se coeff. of sudden expansion=%f ",K_se);
```

Scilab code Exa 18.2 equivalent length

```
clc;
//Example 18.2
```

```
//page no 227
printf("\n Example 18.2 page no 227\n\n");
//cal. equivalent length of pipe that would cause the same head los  for gate and globe valve located in piping
D=3//diameter  of pipe,in
L_gate=7//L/D ratio for fully open gate valve
L_globe=300//L/D ratio for globe valve
L_eq_gate=L_gate*D//equivalent length for gate valve
printf("\n L_eq_gate=%f in",L_eq_gate);
L_eq_globe=L_globe*D//equivalent length for globe valve
printf("\n L_eq_globe=%f in ",L_eq_globe);
```

Scilab code Exa 18.3 pressure drop in a pipe

```
clc;
//Example 18.3
//page no 227
printf("\n Example 18.3 page no 227\n\n");
// water is flowing at room temperature
rho=62.4//density  of water,lb/ft^3
meu=6.72e-4//viscosity of water,lb/ft.s
D=0.03125//diameter of pipe
v=10//velocity
R_e=D*v*rho/meu//reynolds no.
printf("\n reynolds no R_e=%f ",R_e);
f=0.0015+0.125/R_e^.30//equation for friction factor
printf("\n friction factor f=%f ",f);
L=30//length of pipe
gc=32.2//gravitational constant
P_drop=2*f*rho*v^2*L/(D*gc)//pressure drop
printf("\n pressure drop P_drop=%f lbf/ft^2 ",P_drop);
```

Scilab code Exa 18.4 frictional fitting

```
clc;
//Example 18.4
//page no 229
printf("\n Example 18.4 pageno 229\n\n");
//refer to example 18.3
//applying eq 18.4 for friction loss by globe valve
K_f=22//coeff of expansion loss
v=10//velocity
gc=32.2//ravitational constant
h_f=K_f*v^2/(2*gc)//friction loss due to globe valve
printf("\n friction loss due to globe valve h_f=%f
    ft.lbf/lb",h_f);
```

Scilab code Exa 18.5 total pressure drop

```
clc;
//Example 18.5
//page no 230
printf(" Example 18.5 page no. 230\n\n");
//refer to example no. 18.3 and 18.4
P_drop=34.16//pressure drop ,ft
h_f=43//friction loss due to fitting
rho=62.4//density,lb/ft^3
P_d_t=(P_drop+h_f)*rho//total pressure drop
printf("\n total pressure drop P_d_t=%f lbf/ft^2",
    P_d_t);
```

Scilab code Exa 18.6 volumetric flow rate

```
clc;
//Example 18.6
//page no 230
printf("Example 18.6 page no 230\n\n");
k=0.00085//relative roughness of pipe ,ft
D=0.833//diameter  of pipe,ft
f=0.005//we assume fanning friction factor ,0.004-0.005,select upper limit
K=0.45//entrance loss coefficient is estimated from eq. 18.10 and 18.11
L=5000//length of pipe,ft
h_f=4*f*(L/D)//the friction head loss in terms of the line velocity
printf("\n h_f=%f ",h_f);//printing mistake in book 12 instead of 120
//applying bernoulli equation between points 1 and 2 to calculate v2
h_s=0//no shaft head
v1=0//large tank
//because both locations open to the atmosphere,P1=P2=0 psig
h=260//height from point 1 to 2
V2_h=sqrt(h/(1+h_f+K))//total velocity head at point 2
g=32.174
V2=V2_h*2*g
V2=11.75
neu=1.0825e-5//viscosity
R_e=D*(V2)/neu//reynolds number
printf("\n reynolds number R_e=%f ",R_e);//printing mistake in book due to value of h_f
q=V2*(%pi*(D^2)/4)//volumatric flow rate
printf("\n vol. flow rate q=%f ft^3/s",q);//printing mistake in book due to value of h_f
```

Scilab code Exa 18.7 friction loss

```
clc;
//Example 18.7
//page no 232
printf("Example 18.7 page no 232\n\n")
//two large water  reservoirs are connected by a
    pipe
D=0.0779//diameter of pipe (m), by appendix A.5 for
    3 inch schdule 40 pipe
k=0.046*1e-3//roughness of pipe
K_r=k/D//relative roughness
printf("\n relative roughness K_r=%f ",K_r);
q=0.0126//flow rate of water m^3/s,
S=(%pi/4)*D^2//cross sectional area of pipe
v=q/S//flow velocity of water
printf("\n flow velocity v=%f m/s",v);
neu=1e-6//viscosity of water
R_e=v*D/neu//reynolds no
printf("\n reynolds no R_e=%f ",R_e);
//from R_e and relative roughness K_r ,obtain
    friction factor
f=0.00345
L=2000*.3048//length of pipe,m
h_f=4*f*(L/D)*(v^2/2)
printf("\n head loss h_f=%f J/kg",h_f);
//apply bernoulli equation between station 1 and 2.
    Note that P1=P2=1 atm,v1=v2,z1=z2
//P_drop/rho + V^2/2g + z =  h_s - h_f
//whera h_s is the major friction loss
//above equation reduces to h_s=h_f
h_s=h_f//h_s is major friction loss
printf("\n major friction losses h_s=%f J/kg",h_s);
```

Scilab code Exa 18.8 pressure rise in pump

```
clc;
//Example 18.8
//page no 233
printf("\n Example 18.8 page no 233\n\n");
//refer to example no 18.7
rho=1000//density
g=9.807//gravitational acc.
h_f=38.39//head loss
P_rise=rho*g*h_f//pressure rise across the pump
P_rise=475000//in book by mistake this value instead
    original value
q=0.0126//flow rate from example 18.7
W_dot=q*P_rise//ideal pumping requirement(the fluid
    power)
printf("\n W_dot fluid power=%f kw",W_dot);//
    printing mistake in book in putting value of
    P_rise
```

Chapter 19

flow measurement

Scilab code Exa 19.1 air pressure in the oil tank

```
clc;
//Example 19.1
//page no. 246
printf("Example 19.1 page no 246\n\n");
//we have to find pressure at different point in a
    oil tank
//apply manometer equation between point 1 and 2
//since rho1=rho2,z1=z2
//it gives P1=P2
//applying manometer equation between points 2 and 3
rho_oil=0.8*1000//density of oil
//since rho3=rho_oil=rho2
rho3=rho_oil
z_32=.4//height difference between point 2 and 3
g=9.807//grav. acc.
P7=0//pressure at point 7,on gauge basis
z_76=0.8//height difference between point 6 and 7
rho_hg=13600//density of mercury
P6=P7 + rho_hg*g*z_76//pressure at point 6
P5=P6//pressure at point 5
rho_air=1.2//density of air
```

```
z_54=1//height difference between point 5 and 4
P4=P5 + rho_air*g*z_54//pressure at point 4
P3=P4//pressure at point 3
P2=P3 + rho_oil*g*z_32//pressure at point 2
P1=P2//air pressure in the oil tank
printf("\n pressure P1=%f Pag",P1);
```

Scilab code Exa 19.2 pitot tube

```
clc;
//Example 19.2
//page no 250
printf("Example 19.2 page no 250\n\n");
//pitot tube is located at the center line of a horizontal pipe transporting air
rho=0.075//density of gas ,lb/ft^2
h=0.0166667//height difference,ft
g=32.2//gravitational acc. lb/ft^2
rho_m=62.4//density of medium which is air
v=sqrt(2*g*h*(rho_m-rho)/rho)//velocity
printf("\n velocity v=%f ft/s",v);
v_max=v//because at that point where the reading was taken is the centerline
printf("\n maximum veocity v_max=%f ft/s",v_max);
//since the flowing fluid is air at a high velocity the flow has a high probability of being turbilent .from chapter 14,assume
//v_av/v_max=0.815
v_av=v_max*0.815
printf("\n average velocity v_av=%f ft/s",v_av);
```

Scilab code Exa 19.3 mass flow rate

```
clc;
//Example 19.3
//page no 251
printf("Example 19.3 page no 251\n\n");
//refer to example 19.3
S=0.785//cross sectional area,ft^2
v_av=24.4//average velocity,ft/s
q=v_av*S*60//flow rate,factor 60 for minute
printf("\n flow rate q=%f ft^3 min",q);
rho=0.075//density
m_dot=q*rho*60//mass flow rate
printf("\n m_dot mass flow rate=%f lb/hr",m_dot);
```

Scilab code Exa 19.4 volumatric flow rate

```
clc;
//Example 19.4
//page no 251
printf("Example 19.4 page no\n\n")
//water flow ina circular pipe,a pitot tube is used to measure the water velocity
h=0.07//manometer height,m
rho=1000//density of water,kg/m^3
rho_m=13600//density of mercury,kg/m^3
g=9.807
v=sqrt(2*g*h*(rho_m-rho)/rho)
printf("\n water velocity v=%f m/s ",v);
D=0.0779//pipe inside diameter,by using table A.5 in the appendix for a 3 inch schedule 40 pipe
S=(%pi/4)*D^2
printf("/n cross sectional area S=%f m^2",S);
q=v*S//flow rate
printf("\n flow rate q=%f m^3/s",q);
meu=0.001//viscosity of water,kg/m.s
R_e=rho*v*D/meu//reynolds number
```

```
printf("\n reynolds no R_e=%f ",R_e);
```

Scilab code Exa 19.5 venturimeter

```
clc;
//Example 19.5
//page no 254
printf("Example 19.5 page no 254\n\n");
//a venturi meter has gasoline flowing through it.
h=0.035//height of venturi meter
D1=0.06//upsteeam diameter,m
D2=0.02//throat diameter,m
rho_m=13600//density of mercury
rho=680//density of gasoline
g=9.807
v2=sqrt((2*g*h*(rho_m-rho)/rho)/1-D2^4/D1^4)//
    velocity of gasoline at the the throat
printf("\n velocity at throat v2=%f m/s",v2);
q=(%pi/4)*D2^2*v2//flow rate
printf("\n flow rate q =%f m^3/s",q);
P1=101325//upstream pressure,Pa
P2=P1-g*h*(rho_m-rho)//pressure at throat P2
printf("\n pressure P2=%f Pa",P2);
P_d=P1-P2//pressure difference
P_l=.1*P_d//pressure loss is 10 %
printf("\n pressure loss P_l=%f Pa",P_l);
W_l=q*P_l//power loss
printf("\n power loss W_l=%f W",W_l);
```

Scilab code Exa 19.6 flow rate

```
clc;
//Example 19.6
```

```
//page no. 255
printf("\n Example 19.6 page no. 255\n\n");
//refer to example 19.5
//if gasoline has vapor pressure of 50000Pa ,we have
    to calculate flow rate at whhich cavitation to
   occur
P1=101325//upstream pressure,Pa
P2=50000//given vapor pressure,Pa
D1=0.06//upstream diameter,m
D2=0.02//throat diameter,m
rho=680//density of gasoline
v2=sqrt((2*(P1-P2))/rho*(1-D2^4/D1^4))//velocity
printf("\n velocity v2=%f m/s",v2);
q=(%pi/4)*D2^2*v2//flow rate
printf("\n flow rate q=%f m^3/s",q);
```

Scilab code Exa 19.7 orifice meter

```
clc;
//Example 19.7
//page no 258
printf("Example 19.7 page no 258\n\n");
//an  orifice meter is equipped with flange top is
   installed to measure the flow rate of air in a
   circular duct
D1=0.25//diameter of circular duct,m
D2=0.19//orifice diamter,m
v2=4/(%pi*D2^2)//velocity through orifice
printf("\n velocity through orifice v2=%f m/s",v2);
C_o=1// assuming orifice discharge coefficient
rho=1.23//density of air,kg/m^3
P=rho*v2^2*[1-(D2^4/D1^4)]/2//pressure
printf("\n pressure P=%f Pa",P);
meu=1.8e-5// absolute viscosity
R_e=rho*v2*D2/(meu)//reynolds no.
```

```
printf("\n Reynolds no. R_e=%f ",R_e);
C_ac=0.62//actual discharge cefficient ,from fig.19.8
P_ac=P/(C_ac)^2//actual pressure drop
P_rec=14*(D2/D1) + 80*((D2/D1)^2)//equation for
    percentage pressure recovery
P_loss=100-P_rec//precentage pressure loss
P_l=round((P_loss/100)*P_ac)//actual pressure  drop
    after recovery
printf("\n actual pressure drop P_l=%f Pa",P_l);
```

Scilab code Exa 19.9 orifice pressure drop

```
clc;
//Example 19.9
//page no 259
printf("\n Example 19.9 page no 259\n\n");
//air at ambient condition is flowing in a pipe
rho=0.075//density of air ,lb/ft^3
m_dot=0.5//mass flow rate ,lb/s
q=m_dot/rho//volumatric flow rate
printf("\n volumatric flow rate q=%f ft^3/s",q);
```

Chapter 20

ventilation

Scilab code Exa 20.2 diluent volumetric flow rate

```
clc;
//Example 20.2
//page no 269
printf("\n Example 20.2 page no 269\n\n");
//ventilation required in an indoor work area where
   a toluene containing adhesive in a nanotechnology
    process is used.
//equation  for estimate the dilution air
   requirement
C_a=80e-6//concentration of toluene
q=3/8//volumatric flow rate, gal/h
v=0.4//adhesive contains 4 volume % toluene
S_g=0.87//specific gravity
printf("\n C_a concentration of toluene=%f \n q
   volumatric flow rate q=%f gal/h \n S_g specific
   gravity=%f ",C_a,q,S_g);
//mass flow rate of toluene
m_dot_tol=q*v*S_g*(8.34)//factor 8.34 for lb
printf("\n mass flow rate m_dot-tol=%f lb/h",
   m_dot_tol);
m_dot_g=m_dot_tol*(454/60)//unit conversion of mass
```

```
    flow rate in g/min
printf("\n mass flow rate in g/min m_dot_g=%f g/min"
    ,m_dot_g);
M_w=92//molecular weight of toluene
n_dot_tol=m_dot_g/M_w//no. of gm moles of toluene/
    min
printf("\n no. of moles n_dot_tol=%f gmol/min",
    n_dot_tol);
//resultant toluene vapor volumatric flow rate q_tol
     is directly calculated from th eidal gas law
//applying ideal gas law
R=0.08206//gas constant
P=1//standard pressure
T=293//standard temperature
printf("\n R gas constant=%f atm.L/(gmol.K)\n T
    temperature=%f K\n P pressure =%f atm",R,T,P);
q_tol=n_dot_tol*R*T/P//toluene vapor volumatric flow
     rate
printf("\n toluene vapor vol. flow rate q_tol=%f L/
    min",q_tol);
q_tol=2.15//round off value
//the required diluent volumatric flow rtae
K=5//dimensionless mixing factor
q_dil=K*q_tol/(C_a)//diluent vol. flow rate
printf("\n diluent vol. flow rate q_dil=%f L/min",
    q_dil);
```

Scilab code Exa 20.3 limiting reactant

```
clc;
//Example 20.3
//page no 270
printf("Example 20.3 page no 270 \n\n");
// a certain poorly ventilated room chemical stroage
     room has a ceiling fan
```

```
//inside this room bottle of iron(3) sulfide sits next to a bottle sulfuric acid  containg 1 lb H2SO4 in water
// an earthquake sends the botlles on the shelf crashing to the floor where bottles break and their contant mix and react to form iron(3) sulfate and hydrogen sulfide
//we have to calculate maximum H2S concentration that could be reached in the room
Mw_Fe2S3=208//mol. weight of Fe2S3
Mw_H2SO4=98//mol. weight of H2SO4
Mw_H2S=34//mol. weight of H2S
Mw_air=29//mol. weight of air
//balancing chemical reaction
// from the stiochiometric of the reaction ,sulfuric acid is the limiting reagent
// 0.030 lbmol of Fe2S3 is required to react with 0.010 lbmol of H2SO4\
v_r=1600//volume of room,ft^3
n_H2SO4=0.010// lbmol of H2SO4
Stoi_c_H2SO4=3//stoichiometric coeff. of H2SO4
Stoi_c_H2S=3//stoichiometric coeff. of H2S
n_H2S=n_H2SO4*(Stoi_c_H2S/Stoi_c_H2SO4)//lbmol of H2S
printf("\n lbmol of H2S n_H2S=%f lbmol",n_H2S);
m_H2S=n_H2S*Mw_H2S//conversion of moles into mass of H2S
printf("\n mass of H2S m_H2S=%f lb",m_H2S);
//at 32 degF and i atm pressure an ideal gas occupies 359 ft^3 volume then,at 51 deg F occupies
T_r=51//temperature of air in the room
T_st=32//standard temperature
v_st=359//standard volume
printf("\n stand. temperature T_st=%f F\n temperature of air in room T_r=%f F\n stand. volume v_st=%f ft^3",T_st,T_r,v_st);
V_a=v_st*(460+T_r)/(460+T_st)//volume of air
```

```
printf("\n volume of air at 51deg F V_a=%f ft^3",V_a);
//the final concentration of H2S in the room in ppm C_H2S
C_H2S=m_H2S*(V_a/Mw_air)*1e+6/(v_r)
printf("\n conc. of H2S in ppm C_H2S=%f ppm",C_H2S);
```

Scilab code Exa 20.4 vinyl chloride application

```
clc;
//Example 20.4
//Page no 271
printf("Example 20.4 page no 271\n\n");
//vinyl chloride application
//calculation of density by using ideal gas law
Mw=78//molecular weight of vinyl chloride
R=82.06//gas constant,cm^3.atm/mol.K
T=298//temperature,K
P=1//pressure ,atm
rho=P*Mw/(R*T)//density of vinyl chloride
printf("\n rho density of vinyl chloride=%f g/cm^3",rho);
//given
m_dot=10//mass flow rate,g/min
q=m_dot/rho//volumatric flow rate
printf("\n vol. flow rate q=%f cm^3/min",q);
q_acfm=0.1107//vol flow rate in acfm
//cal. the air flow rate in acfm q_air required to meet the 1.0 ppm constraint with the equation
q_air=q_acfm/1e-6
printf("\n vol.flow rate q_air=%f acfm",q_air);
S_factor=10//correct for mixing by employing a saftey factor
//apply saftey factor to calculate the actual air flow rate for dilution ventilation
```

```
q_dil=S_factor*q_air
printf("\n air flow rate for dilution q_dil=%f acfm"
    ,q_dil);
//now consider the local exhaust ventilation by
    first calculating the face area
H=30//height of hood,in
W=25//width of hood,in
S=H*W/144//surface area of hood ,ft^2
//the air flow rate in acfm q_air,exh required for a
     face velocity of 100 ft/min is then
v=100//face velocity,ft/min
q_exh=round(S*v)
printf("\n air flow rate q_exh=%f acfm",q_exh);
```

Scilab code Exa 20.7 ventilation flow rate

```
clc;
//Example 20.7
//page no 276
printf("\n Example 20.7 page no 276\n\n");
//refer to illustrative Example 20.5
//(1)
//we have to calculate minimum air ventilation flow
    rate into the room containing 10 ng/m^3 of a
    toxic chemical
//ng means nanograms
rV=250//chemical generated in the laboratory,ng/min
c_o=10//room containg toxic chemical of 10ng/m^3
c=35//limit of chemical concentration,ng/m^3
//applicable modal in this case
//q_o(c_o-c) + rV  =V*dc/dt
//substituting gives
q_o=(-rV)/(c_o-c)//minimum air ventilation flow rate
printf("\n q_o min. air ventilation flow rate=%f m
    ^3/min",q_o);
```

Scilab code Exa 20.8 ventilation air

```
clc;
//Example 20.8 page no 277
printf(" Example 20.8 page no 277\n\n");
//refer to example no 20.5 and 20.7
V=142//volume of room,m^3
q=12.1// flow rate of air,m^3/min
tou=V/q//time ,min
r=30//rate of generation of chemical,ng/min
k=r/V//ng/(m^3.min)
c_i=85//intial concentration in laboratory,ng/m^3
c_o=10//given concentration in room
c=20.7//final concentration in room
//by using  trial and error mthod we get
function y=f(t)
  y=c_i*(exp(-t/tou))+ (c_o+k*tou)*(1-exp(-t/tou)) -
      c
endfunction
t=fsolve(30,f);
//by using trail and error method we get
t=29
printf("\n t=%f min ",t);
```

Chapter 21

academic application

Scilab code Exa 21.7 reynolds number

```
clc;
//Example 21.7
//Page no 284
printf("Example 21.7 page no 284\n\n");
// water is flowing through a 3/8 in schedule 40 brass pipe
D=0.0411//diameter of pipe,ft
S=0.00133//cross section area of pipe,ft^2
meu=6.598e-4//viscosity of water from table A.4 in the appendix,lb/ft.s
rho=62.4//density,lb/ft^3
q_gpm=2//vol.flow rate
q=q_gpm*0.00228//volumatric flow rate in ft^3s
v=q/S//velocity of fluid
printf("\n veloctiy of fluid v=%f ft/s",v);
R_e=D*v*rho/meu//reynolds no.
printf("\n reynolds no R_e=%f ",R_e);
```

Scilab code Exa 21.8 reynolds number

```
clc;
//Example 21.8
//page no 285
printf("Example 21.8 page no 285\n\n");
//water flowing through a pipe
rho=62.4//density of water,lb/ft^3
meu=6.72e-4//viscosity of water,lb/ft.s
q_1gpm=1.5//vol. flow rate in gpm
q_2gpm=6//vol. flow rate in gpm
D_1=0.493//internal diameter of 3/8 in schdule pipe
v11=(0.409*q_1gpm)/(D_1^2)//flow velocity for an 3/8 in pipe with 1.5 gpm flow rate
v12=(0.409*q_2gpm)/(D_1^2)//flow velocity for an 3/8 pipe with 6 gpm flow
R_e11=D_1*v11*rho/meu//reynolds no for case 11
R_e12=D_1*v12*rho/meu//reynolds no for case 12
printf("\n reynolds no R_e11=%f\n reynolds no R_e12=%f ",R_e11,R_e12);//printing mistake in book
D_2=0.622//internal diameter of 1/2 in schdule pipe
v21=(0.409*q_1gpm)/D_2^2//flow velocity for 1/2 pipe with 1.5 gpm
v22=(0.409*q_2gpm)/D_2^2//flow velocity for 1/2 pipe with 6 gpm
R_e21=D_2*v21*rho/meu//reynolds no for case 21
R_e22=D_2*v22*rho/meu//reynolds no foe case 22
printf("\n reynolds no R_e21=%f\n reynolds no R_e22=%f",R_e21,R_e22);
//printing mistake in value of R_e
```

Scilab code Exa 21.9 pressure drop

```
clc;
//Example 21.9 page no 286
printf("Example no 21.9 page no 286\n\n");
//water is flowing in a vertical pipe
```

```
//assume constant velocity
P_drop=-4.5//pressure drop from bottom to top
rho=62.4 //density of water
z2=15//height of pipe
z1=0//bottom level
//applying bernoulli equation
h_f=(P_drop/rho)+(z2-z1)//frictional loss
printf("\n frictional loss h_f=%f ft.lbf/lb ",h_f)
```

Scilab code Exa 21.10 centrifugal pump

```
clc;
//Example 21.10
//page no 286
printf("Example 21.10 page no 286\n\n");
//a centrifugal pump is needed to transport water
   from sea level to 10000 feet above sea level
//using bernoulli equation
//neglectiing kinetic energy effects and frictional
   losses
P1=14.7//atmospheric pressure at sea level,psi
P2=10.2//atmospheric pressure at 10000 feet,psi
z1=0//at sea level,ft
z2=10000//height above sea level,ft
rho=62.4//density of water
g=32.2//gravitational acc.
g_c=32.2//gravitational constant
h_s=((P2-P1)*144/(rho)  + (z2-z1)*(g/g_c))//work
   deliverd by the pump to the water,in ft.lbf/lb
h_s=9990//ft.lbf/lb
h_sf=h_s*50//in ft.lbf
printf("\n work h_sf=%f ft.lbf/s",h_sf);
//actual pump work is calculated by dividing the
   above terms by the frictional afficiency
neta=0.65//frictional efficiency
```

```
W_p=round((h_sf/550)/neta)//actual work
printf("\n actual work W_p=%f hp",W_p);
```

Scilab code Exa 21.12 friction loss

```
clc;
//Example 21.12
//page no 288
printf("Example 21.12 page no 288\n\n");
//refer to illustrative Example 21.4
// if the pipe contains two globe valves and one
    straight through tee,what is the friction loss
K_f_globe=6
K_f_tee=0.4
v=2.53// flow velocity
g_c=32.2
f=5/4//friction factor
L=144//lenth of pipe
D=62.4//diameter
h_f=4*f*(L/D) + (2*K_f_globe + K_f_tee)*(v^2/(2*g_c)
    )
printf("\n frictional loss h_f=%f ft.lbf/lb",h_f);
```

Scilab code Exa 21.13 pitot tube

```
clc;
//Example 21.13
//page no 289 figure 21.1
printf("Example 21.13 page no 289 fig 21.1  \n\n\n")
    ;
//a pitot tube is inserted in acircular pipe  to
    measure the flow velocity
```

```
// the tube is inserted so that it points upstream into the flow and the pressure sensed by thre probeis the stagnation pressure
//the change in elevation between the tip of the pitot and the wall pressure tap is negligible
//the flowing fluid is soyabean oil at 20 deg C and the fluid in manometer tube is mercury
//point 2 is a stagnation point ,P2>P1 and the manometer fluid should be higher on th eleft side (h<0)
rho_m=13600//density of mercury,kg/m^3
h=0.04//height of mercury,
rho=919//density of oil kg/m^3
g=9.804
D=0.055//diameter of pipe,m
meu=0.04//viscosity of oil,kg.m.s
v=sqrt(2*g*h*((rho_m/rho)-1))//flow velocity
printf("\n flow velocity v=%f m/s",v);
//assuming uniform velocity
S=(%pi/4)*D^2
m_dot=rho*v*S//mass flow rate
R_e=(D*v*rho)/meu//reynolds no
printf("\n reynolds no R_e=%f ",R_e);
printf("\n mass flow rate m_dot=%f kg/s",m_dot);
```

Scilab code Exa 21.14 flow rate

```
clc;
//Example 21.14
//page no 290
printf("Example 21.14 page no 290\n\n");
//given: a 50 ft pipe with flowing water ,we have to determine the flow rate if there is an expansion from 3/8 inch to 1/8 inch and immediatly back to 3/8n inch with an overall pressure loss no
```

```
    greater than 2lbf/ft^2
//from table A.5 in the appendix
S1=0.00133//cross sectional area of 3/8 inch pipe,ft
    ^2
S2=0.00211//cross sectional area of 1/2 inch pipe,ft
    ^2
K_e=(1-S1/S2)^2//expansion constant
K_c=0.4*(1-S2/S1)^2//contraction constant
L=50//length of pipe
D=0.03125//diameter of pipe
v=1.93//velocity ,ft/s
f=0.01124//friction factor from table 21.3,for
    velocity estimated to be 1.93 ft/s
g_c=32.2
h_f=(4*f*L/D  + K_e + K_c)*(v^2*g_c)//frictional
    loss
printf("\n frictional loss h_f=%f ft.lbf/lb ",h_f);
```

Scilab code Exa 21.16 pressure drop

```
clc;
//Example 21.16
//page no 291
printf("Example 21.16 page no 291\n\n");
//water flows in a concrete pipe
v_p=0.02// flow velocity ,m/s
D_p=1.5//diameter of pipe
L_p=20//length of pipe ,m
rho_p=1000//density of water,kg/m^3
meu_p=0.001//viscosity of water,kg/m.s
K_p=0.003//roughnes factor ,m
//this prototype is to be modeled in a lab using a
    1/3o th scale pipe
D_m=D_p/30//D_m is diameter of modeled pipe
L_m=L_p*(D_m/D_p)//length of modeled pipe
```

```
K_m=K_p*(D_m/D_p)//roughness factor for modeled pipe
//the fluid in the model is caster oil
rho_m=961.3//densiy of oil , kg/m^3
meu_m=0.0721//viscosity of oil ,kg/m.s
//since R_e = (rho_m*v_m*D_m)/meu_m  =  (rho_p*v_p*D_p)/meu_p
v_m = (rho_p*v_p*D_p*meu_m)/(rho_m*D_m*meu_p)// flow velcity in molded pipe
printf("\n flow velocity v_m=%f m/s",v_m);
//pressure drop in prototype
P_drop_m=1e+5//pressure drop in model
P_drop_p=(P_drop_m*rho_p*(v_p)^2)/(rho_m*(v_m)^2)// pressure drop in prototype
printf("\n pressure drop in prototype P_drop_p=%f Pa",P_drop_p);
```

Chapter 22

industrial application

Scilab code Exa 22.4 centrifugal pump

```
clc;
//Example 22.4
//page no 298
printf("Example 22.4 page no 298\n\n");
//a centrifugal pump operating at 1800 rpm ,we have
    to find the impeller diameter needed to develop a
     head of 200 ft
h=200//height ,ft
g=32.2//gravitational acc. ft/s^2
v=sqrt(2*g*h)//velocity needed to develop a head of
    200 ft
printf("\n velocity v=%f ft/s",v);
N=1800//pump operating at this rotational speed ,in
    rpm
c=v*60/N//the number of feet that the impeller
    travels in one rotations
//this c represents the circumference of the
    impeller  since it is equal to one rotation
printf("\n circumference c=%f ft/rotation",c);
D=c/%pi//diameter of the impeller
printf("\n diameter D=%f ft",D);
```

Scilab code Exa 22.5 total energy required

```
clc;
//Example 22.5
//page no 299
printf("Example 22.5 page no 299\n\n");
//water for a processing plant is required to be
   stored in a reservoir
//assume the properties of water at 20 deg C are
rho=998//density ,kg/m^3
meu=0.001//viscosity ,N.s/m^2
L=120//length of pipe ,m
D=0.15//diameter  of pipe ,m
S=(%pi/4)*D^2//cross sectional area of pipe
//given:
q=1.2/60//volumetric flow rate ,m^3/s
v=q/S//flow velocity ,m/s
R_e=D*v*rho/meu//reynolds no
printf("\n reynolds no R_e=%f ",R_e);
//from value of R_e ,flow is clearly turbulent
k=0.0005//roughness factor for galvanized iron
K_r=k/D//relative roughness
f=0.0053//fricion factor from fig. 14.2
h_f=4*f*(L/D)*(v^2/2)//friction loss of energy
printf("\n h_f frictional  loss=%f J ",h_f);
//for right elbows (from table 18.1),the estimated
   value of resistance coff. K for one regular 90
   deg elbows is 0.5
K=4//resstance coeff.
V_h=v^2/2//velociy head
e_l=K*V_h//the total loss from the elbows
printf("\n e_l total elbow loss=%f J/kg",e_l);
//the energy to move 1 kg of water against a head of
    22m of water is
```

```
z=22//height ,m
g=9.81//grav. acc ,m/s^2
PE=z*g
printf("\n potential energy PE=%f J/kg",PE);
TE = h_f + e_l  + PE//total requirement per kg
printf("\n total energy TE=%f J/kg",TE);
W_dot_s= TE*q*rho//theoretical power requirement
printf("\n theoritical power W_dot_s=%f J/s",W_dot_s);
h=TE/g//head equivalent to the energy requirement
printf("\n equivalent head h=%f m ",h);
```

Scilab code Exa 22.6 reynolds number and head

```
clc;
//Example 22.6
//page no 301
printf("Example 22.6 page no 301\n\n");
//oil is flowing through a standard 3/2 inch steel pipe containing a 1 inch square edged orifice
v_gal=400//orifice velocity of oil in gal/hr
v_o=400*144/(0.785*3600*7.48)//orifice velocity in ft/hr
D_o=1/12//diameter of orifice
rho=0.87*62.4//density of oil
meu=20.6*0.000672//viscosity of oil
R_e=D_o*v_o*rho/meu
printf("\n reynolds no =%f ",R_e);
D_r=0.62//ratio of orifice plate to pipe diametersD_o/D1 = 1/1.61
C_d=0.76//discharge coeff. fro fig 19.8
g=32.2//grav. acc. ft/s^2
h=(v_o^2/(2*g*(C_d)^2))*(1-D_r^4)//height of oil in gauge reading
printf("\n gauge reading h=%f ft ",h);
```

Scilab code Exa 22.7 mass flow rate

```
clc;
//Example 22.7
//page no 302
printf("Example 22.7 page no 302\n\n ");
//natural gas consisting of essentially pure methane flows through a long straight standard 10 inch steel pipe into which is inserted a square edged orifice 2.50 inches in diameter ,with pressure taps ,each 5 inch from the orifice plate
//manometer is attached across the orifice reads 1.60 in H20
D_o=2.50//diameter of orifice
D_1=10.15//diameter of plate
D_r=D_o/D_1//ratio of diameters
//assuming the reynolds no R_e in the orifice to be over 30,000
C_o=0.61//coeff. of discharge from R_e value
g=32.2//garv. acc ft/s^2
rho_m=62.4//density of medium (water)
rho=0.054//density of methane gas,lb/ft^3
h=1.60//manometer reading height,in
meu=12*0.011*0.000672//viscosity
v_o= C_o*sqrt((2*g*h*rho_m)/(12*rho))// orifice velocity
printf("\n orifice veloctiy v_o=%f ft/s",v_o);
R_e_o=D_o*v_o*rho/meu//reynolds no in the orifice
printf("\n R_e_o reynolds no =%f ",R_e_o);
//from R_e_o value C_o=0.61 is permissible
m_dot=round(v_o*(%pi/4)*(D_o^2)*rho*(3600/144))//mass flow rate
printf("\n mass flow rate m_dot=%f lb/hr",m_dot);
```

Scilab code Exa 22.8 gradual contraction

```
clc;
//Example 22.8
//page no 303
printf("Example 22.8 page no 303\n\n");
//refer to fig 22.1
D1=.1//upstream diameter(at station 1),m
D2=.06//downstream diameter(station 2),m
S2=(%pi/4)*D2^2//cross sectional area at point 2
rho=1.22//density of air  from ideal gas law
rho_m=827//density of medium,kg.m^3
g=9.8//gravitational acc.
h=0.08//manometer head,m
//from bernoulli equation
v2=sqrt(2*g*h*((rho_m/rho)-1))//velocity at point 2
v1=v2*(D2/D1)^2//velocity at point 1
q=v2*S2//volumatric flow rate
printf("\n vol.flow rate q=%f m^3/s",q);
//calculation of mach number from equation 15.1
T=293//temperature in k
c=20*sqrt(T)//speed of light at this temperature,m/s
M_a=v2/c//mach no.
printf("\n mach no. M_a =%f ",M_a);
//noting that M_a=0.095 < 0.3 , we can conclude that
    flow is incompressible//given
P1=130000 //absolute pressure at point 1,pa
//by using bernoulli eq for P2
P2=P1-rho*v2^2*(1-(D2/D1)^4)/2//pressure at point 2
printf("\n pressure at point 2=%f Pa",P2);
```

Scilab code Exa 22.9 friction loss in the conduit

```
clc;
//Example 22.9
//page no 305
printf("\n Example 22.9 page no 305\n\n");
//water is flowing from an elevated reservoir through a conduit to a turbine at a lower level and out of the turbine through a similar conduit
//refer to fig 22.2
//since the diameter of the conduit is the same at location 1 and 2 ,kinetic energy effects can be neglected and bernoulli eq. takes the form
//P/rho + z(g/g_c) -h_s + h_f = 0
P1=30///pressure at point 1,psia
z1=300//height of point 1,ft
P2=18//pressure at point 2,psia
z2=-10//height of point 2,ft
rho=62.4//density
m_dot=3600//mass flow rate,tons/hr
W_dot =1000//output at the shaft of turbine,hp
neta=0.9//efficiency of turbine
h_s=W_dot*550*3600/(neta*m_dot*2000)//
printf("\n h_s =%f ft.lbf/lb",h_s);
//put this value in bernoulli eq.
h_f=(P2-P1)*144/rho + (z2-z1) -h_s//frictional loss
printf("\n frictional loss h_f=%f ft.lbf/lb",h_f)
```

Scilab code Exa 22.10 discharge and NPSH

```
clc;
//Example 22.10
//page no 306
printf("\n Example 22.10 page no 306\n\n");
//benzene is pumped from a large tank to a delivery station
//refer fig 22.3
```

```
q=0.003//vol. flow rate,m^3/s
//tank is at atmosphric pressure
D=0.03//diameter of suction and discharge line,m
v_2=q/((%pi/4)*D^2)//discharge velocity,m/s
//since all diameters are same likewise velocities are same
v_3=v_2
g=9.807//grav. acc.
D_h=(v_3^2)/(2*g)//dynamic head
printf("\n dynamic head D_h=%f m",D_h);
z1=0//height at point 1,tank level
z2=1.8//height at point 3
//applying bernoulli's eq. between the top of the tank(open to theatomsphere)and the inlet to the pump(station3)
rho=865//density of benzene,kg/m^3
P3=101325-(z2+D_h)*(rho*g)//ptressure at point 3
printf("\n pressure at point 3 P3=%f Pa",P3);
P_v=26200//vapor pressure of benzene,Pa
NPSH = (P3 - P_v)/(rho*g) + D_h
printf("\n NPSH=%f m",NPSH)
//the manufacturer NPSH is 8 m, which is greater than the calculated NPSH of 7.06m,therfore, the suction point of pump must be lowered
//calculation of new pressure
NPSH_m=8//NPSH by manufacturer
P3_n_ab=8*(rho*g)-D_h*(rho*g) + P_v
printf("\n new pressure at point 3 P3_n_ab=%f Pa absolute",P3_n_ab);
P3_n_bz=-1.77//pressure in terms of benzene height,m
z3=-P3_n_bz -D_h//desired height of point 3
printf("\n height z3=%f m",z3);
```

Scilab code Exa 22.11 pump requirement in hp

```
clc;
//Example 22.11
//page no 308
printf("Example 22.11 page no 308\n\n");
//a storage tank on top of a building pumps 60 deg F
    water through an open pipe to it from a
   reservoir
q=1.36//vol. flow rate ,ft^3/s
D=0.333//diameter of pipe,ft
S=%pi/4*D^2//cross sectional area,ft^2
v2=q/S//flow velocity,ft/s
rho=62.37//density of water,lb/ft^3
meu=1.129*6.72e-4//viscosity of water
R_e=D*v2*rho/meu//reynolds no.
printf("\n reynolds no. R_e=%f",R_e );
//from R_e we can conclude that flow is turbulent
k=0.0018//roughness factor
K_r=k/D//relative roughness
f=0.0046//friction factor
L=525//length of pipe,ft
g_c=32.174//grav. acc
h_fp=(4*f*L*v2^2)/(D*2*g_c)//frictional loss due to
   the length of pipe
printf("\n frictional loss h_fp=%f ft.lbf/lb",h_fp);
//friction due to the fitings from table 18.1
K_ff_gate=2*0.11//loss coeff. due to gates
K_ff_elbows=5*0.64//loss coeff. due to elbows
//friction due to the sudden contraction is obtained
    from eq. 18.10 .
//note that D1/D2=0,since the upstream diameter is
   singnificantly larger than the downward diameter
K_c=0.42//coeff. of sudden contraction
K_e=1//coeff. of sudden expansion
K_s=K_ff_gate +K_ff_elbows +K_e +K_c//sum of loss
   coeff.
h_f=K_s*v2^2/(2*g_c)//friction losses due to fitting
   ,expansion,contraction
h_f_total=h_fp + h_f//total frictional losses
```

```
printf("\n total frictional loss h_f_total=%f ft.lbf
    /lb",h_f_total);
v1=0
P_drop=0//pressure drop
z1=0//reservoir water level
z2=200//height of reservoir
W_s=(v2^2-v1^2)/(2*g_c)  + (z2-z1)  + h_f_total//
    power requirement
m_dot=q*rho//mass flow rate,lb/s
neta=0.6//efficiency of pump
W_dot_s=m_dot*W_s/(550*neta)//actual horsepower
    requirement
printf("\n W_dot_s=%f hp",W_dot_s);
```

Scilab code Exa 22.12 friction loss

```
clc;
//Example 22.12
//Page no 311
printf("Example 22.12 page no 311\n\n")
//turpentine is being moved  from a large storage
    tank to a blender through a 700 ft pipeline
rho=62.4//density
SG=0.872//specific gravity of terpentine
rho_t=SG*rho//density of turpentine
v=12.67//av. velocity of the turpentine in the line,
    ft/s
z1=20//height of top surface in the storage tank
    above floor level,ft
z2=90//height of discharge end of pipe,ft
neta=0.74//efficiency of pump
W_s=401.9//average energy delivered by pump,ft/lbf/
    lb
g_c=32.174//grav.acc
L=700//length of pipeline
```

```
//from bernoulli eq.
h_f= neta*W_s - v^2/(2*g_c) - (z2-z1)//frictional loss  if there is no pressure drop
printf("\n frictional loss h_f =%f ft.lbf/lb",h_f);
k_c=0.4//coeff. of contraction
k_e=0.9//coeff. of expansion
k_f=0.2//coeff. of bends and valve
//making equation(1) from the friction coeff. due to fittings between f and D,f=0.0293*D
//making another equation(2) from Reynolds number in terms D ,R_e=582250*D
//from trial and error method we get D
D=0.184//diameter
S=%pi*D^2/4//cross sectional area
S=0.0266
q=v*S//volumetric flow rate
printf("\n q=%f ft^3/s ",q);
m_dot=rho_t*q//mass flow rate
bhp =m_dot*W_s/(550*neta)//brake horse power
printf("\n brake horse power bhp=%f hp",bhp);
```

Scilab code Exa 22.13 friction loss and friction power loss per unit length of pipe

```
clc;
//Example 22.13
//page no 313
printf("Example 22.13 page no 313\n\n");
//hydrogen flows through a horizontal pipe
//properties of hydrogen at 20 deg C from table A.3 in the appendix
rho=0.0838//density of hydrogen,kg/m^3
meu=9.05e-6//viscosity,kg/m.s
D=0.08//diameter of pipe,m
L=1//unit length of pipe,m
```

```
q=0.0004//vol. flow rate ,m^3/s
S=.000503//cross sectional area
v=q/S//flow velocity ,m/s
m_dot=rho*q//mass flow rate ,kg/s
R_e=(D*v*rho/meu)//reynolds no.
printf("\n R_e reynolds no=%f ",R_e);
//since R_e is 593<2100, flow is laminar
//since the tube is horizontal z1=z2,calculation of
    pressure gradient(P/L)
P_grad= 128*meu*q/(%pi*D^4)//pressure gradient
printf("\n Pressure gradient P_grad=%f Pa/m",P_grad)
v_max=2*v//m/s
//calculation of fanning friction factor
//since the flow is laminar
f=16/R_e//fanning friction factor
printf("\n fanning friction factor f=%f ",f);
f_d=4*f//darcy friction factor
printf("\n darcy friction factor f_d=%f ",f_d);
g=9.807//grav. acc.
h_f=f_d*(L/D)*(v^2/(2*g))//friction loss
printf("\n friction loss h_f=%f m",h_f);
W_f = m_dot*g*h_f//friction power loss
printf("\n friction power loss W_f=%f W",W_f);
```

Scilab code Exa 22.14 average velocity of gasoline

```
clc;
//Example 22.14
//page no 315
printf("\Example 22.14 page no 315\n\n");
//gasoline is pump through a horizontal cast iron
    pipe
L=30//length of pipe
D=0.2//diameter of pipe ,m
S=(%pi/4)*D^2//cross sectional area
```

```
q=0.3//vol. flow rate ,m^3/s
v=q/S//flow velocity ,m/s
rho=680//density of gasoline ,kg/m^3
meu=2.92e-4//viscosity of gasoline ,kg/m.s
R_e=D*v*rho/meu//reynolds no.
printf("\n reynolds no R_e=%f ",R_e);
//since R_e is >4000 flow is turbulent
k=0.00026//roughness factor from table 14.1 for cast iron ,m
K_r=k/D//relative roughness
f=0.00525//fanning friction factor from fig 14.2
//Note that the flow corresponds to complete turbulence in the rough pipe
g=9.807//gravitational acceleration
//h_f=4*f*(L/D)*(v^2/(2*g))//head loss
h_f=14.647
//applying bernoulli equation to the fluid in the pipe
//in this case the pipe is horizontal (z1=z2) with constant diameter (v1=v2) and no shaft head (h_s=0)
//first convert the friction head to a pressure difference
P_diff=rho*g*h_f//pressure difference
P_diff= 97.68*10^3//after round off
W_s_id=q*P_diff//ideal shaft work
printf("\n ideal shaft work W_s_id=%f W ",W_s_id);
neta=0.8//efficiency of pump
W_s_ac=W_s_id/neta//actual shaft work
printf("\n actual shaft work W_s_ac=%f W",W_s_ac);
f_s=0.009//friction factor smooth
f_r=0.021//friction factor roughnes
k=f_r/f_s
f_inc=100*(k-1)//percentage increment in f due to roughness
printf("\n f_inc=%f ",f_inc);
```

Scilab code Exa 22.15 average velocity of the benzene

```
clc;
//Example 22.15
//page no 316
printf("\n Example 22.15 page no 316\n\n")
//liquid benzene flows through a smooth horizontal
   iron pipe
D=2.3//diameter of pipe,m
L=146.304//length of pipe,m
S=(%pi/4)*D^2//cross sectional area,m^2
q=4000//vol. flow rate,gal/min
v=q/(S*264.17*60)//flow velocity
printf("\n flow velocity v=%f m/s",v);
rho=899//density of benzene
meu=0.0008//viscosity of benzene,kg/m.s
R_e = D*v*rho/meu//reynolds no
printf("\n reynolds no R_e=%f ",R_e);
//since the reynolds number falls in the turbulent
   regime,determine the fanning friction factor from
    fig. 14.2
f=0.0032//fanning friction factor
// calculation of pressure drop with the assumption
   of no height and velocity change , and no pump
   work
//since only frictional losses are to be considered
//applying eq. 14.3
P_drop = 4*f*(L/D)*(v^2/2)*rho//pressure drop
printf("\n pressure drop P_drop=%f Pa",P_drop);
W_dot_f=q*P_drop/(264.17*60)//friction power loss
printf("\n friction power loss W_dot_f=%f W",W_dot_f
   );
```

Scilab code Exa 22.16 steam flow rate

```
clc;
//Example 22.16
//page no 317
printf("\n Example 22.16 page no 317\n\n");
//a power plant employs steam to generate power
//adiabatic conditions
z1=0//steam vertical position at inlet,ft
z2=-20//steam vertical position at outlet,ft
v1=120//steam velocity at inlet,ft/s
v2=330//steam velocity at outlet,ft/s
H1=1505.4//steam enthalpy at inlet
H2=940//steam enthalpy at outlet
Q=0//for adiabatic conditions
g_c=32.174//grav .acc
//applying energy equation
W_s=-(z2/778) - v2^2/(2*g_c*778) - H2  +z1 + v1
    ^2/(2*g_c*778) + H1//work extracted from system
printf("\n work extracted from the system W_s=%f Btu
    /lb ",W_s);
m_dot=450000//mass flow rate ,lb/h
W_dot_s=m_dot*W_s//total power generated by the
    turbine
printf("\n W_dot_s =%f Btu/h",W_dot_s);//approx
    calculation in book
W_hp=W_dot_s*3.927e-4//power generated in horsepower
     hp
printf("\n power generated W_hp=%f hp",W_hp);//
    approx calculation in book
```

Chapter 23

particle dynamics

Scilab code Exa 23.1 aerodynamic diameter

```
clc;
//Example 23.1 page no 323
printf("Example 23.1 page no 323\n\n");
//calculation of aerodynamic diameter for the following particles
d_es=1.4//equivalent dia of solid sphere,micrometer
sg_s=2//specific gravity of solid sphere
d_eh=2.8//equivalent diameter of hollow sphere, mirometer
sg_h=0.51//specific gravity of hollow sphere
d_pa1=d_es*sqrt(sg_s)//aerodynamic dia for solid sphere
d_pa2=round(d_eh*sqrt(sg_h))//aerodynamic dia for hollow sphere
printf("\n d_pa1=%f micron\nd_pa2=%f micron",d_pa1,d_pa2);
```

Scilab code Exa 23.2 aerodynamic diameter

```
clc;
//Example 23.2 page no 323
printf("Example 23.2 page no 323\n\n");
//calculation of aerodynamic diameter of irregular
   saped sphere
d_e=1.3//eq. diameter,micron
sg=2.35
d_pa=d_e*sqrt(sg)//aerodynamic diameter
printf("\n aerodynamic diameter d_pa=%f micron",d_pa
   );
```

Scilab code Exa 23.3 cunningham correction factor

```
clc;
//Example 23.3 page no 335
printf("Example 23.3 page no 335\n\n");
//calculation of cunningham correction factor
dp=0.4//particle diameter
lemda=6.53e-2
A=1.257 + 0.40*exp(-1.10*dp/(2*lemda))
C= 1 + 2*A*lemda/dp//cunningham correction factor(
   CCF)
printf("CCF C=%f ",C);
```

Scilab code Exa 23.4 particle terminal velocity

```
clc;
//Example 23.4
//page no 336
printf("Example 23.4 page no 336\n\n");
//three different diameter sized fly ash particls
   settle through air
```

```
//we have to calculate the particle terminal velocity and determine how far each will fall in 30 seconds
//assume the particles are speherical
SG=2.31//specific gravity of fly ash
rho_w=62.4//density of water
rho_p=SG*rho_w//density of particles
//properties of air
R=0.7302//gas constant
T=698//temperature,R
P=1//pressure ,atm
Mw=29//mol. wt of air
rho_a=P*Mw/(R*T)//density of air,lb/ft^3
meu=1.41e-5//viscosity of air,lb/ft.s
g=32.174//grav. acc
D1=0.4//diameter of particle 1,microns
D2=40//diameter of particle 2,microns
D3=400//diameter of particle 3,microns
K1=(D1/(25400*12))*(g*rho_p*rho_a/(meu^2))^(1/3)//dimensionless constant for particle 1
K2=(D2/(25400*12))*(g*rho_p*rho_a/(meu^2))^(1/3)//dimensionless constant for particle 2
K3=(D3/(25400*12))*(g*rho_p*rho_a/(meu^2))^(1/3)//dimensionless constant for particle 3
printf("\n dimensionless constant K1=%f \n K2=%f \n K3=%f ",K1,K2,K3);
//first we determine which fluid particle dynamic law applies for the above values of K
//for particle 1,strokes law applies
//for particle 2,strokes law applies
//for particle 3,intermediate law applies
//terminal settling velocity for each particle
v1=(D1/(25400*12))^2*g*rho_p/(18*meu)
printf("\n terminal settling velocity for particle 1 v1=%f ft/s",v1);
v2=(D2/(25400*12))^2*g*rho_p/(18*meu)
printf("\n terminal settling velocity v2=%f ft/s",v2);
```

```
v3=(D3/(25400*12))^1.14*0.153*g^0.71*rho_p^0.71/(rho_a^0.29*meu^0.43)
printf("\n terminal settling velocity v3=%f ft/s ",v3);
//calculation of how far x,the fly ash particles will fall in 30 seconds
t=30//time,sec
x2=v2*t//distance travel by 2 particle
x3=v3*t//distance travel by 3 particle
printf("\n distance by 2 particle x2=%f ft\n distance by 3 particle x3=%f ft",x2,x3);
//for 1 particle K1 and v1 value are without the CCF.With the correction factor lemda=6.53e-8,gives
lemda=6.53e-8//correction factor
y=-1.10*(D1/(25400*12))/(2*lemda)
A =1.257 + 0.40*exp(y)
C=1 + 2*A*lemda/(D1/(25400*12))//cunningham correction factor(ccf)
//now equation 23.36 can be employed
v1_corrected=v1*C//corrected velocity of 1 particle
x1=v1_corrected*t//distance travel by 1 particle
printf("\n distance travel by 1 particle x1=%f ft",x1);
```

Scilab code Exa 23.5 size of fly ash particle

```
clc;
//Example 23.5
//page no 338
printf("\n Example 23.5 page no 338\n\n");
//refer to example 23.5
//we have to calculate size of a flyash particle that will settle with a velocity of 1.384 ft/s
SG=2.31//specific gravity of fly ash
rho_w=62.4//density of water
```

```
rho_p=SG*rho_w//density of particles
//properties of air
R=0.7302//gas constant
T=698//temperature ,R
P=1//pressure ,atm
Mw=29//mol. wt of air
rho_a=P*Mw/(R*T)//density of air ,lb/ft^3
meu=1.41e-5//viscosity of air ,lb/ft.s
g=32.174//grav. acc
v=1.384//velocity at which particle settle down,ft/s
W= v^3*rho_a^2/(g*rho_p*meu)//dimensionless constant
printf("\n dimensionless constant W=%f ",W);
//since W < 0.2222 stokes' law applies
D_p=sqrt(18*meu*v/(g*rho_p))//diameter of particle
printf("\n diameter of particle D_p=%f ft",D_p);
```

Scilab code Exa 23.7 average height of soap particles

```
clc;
//Example 23.7
//page no 340
printf("\n Example 23.7 page no 340\n\n");
// In a plant manufacturing ivory soap detergent
   explodes one windy day
//we have to calculate the distance from the plant
   where the soap particles will start to deposit
   and where they will cease to deposit
//the smallest particle wll travel the greatest
   distance while the largest will travel the least
   distance
//for the minimumdistance ,we use largest particle
D_l=3.28e-3//largest diameter,ft
g=32.174//grav. acc.
SG=0.8//specific gravity of soap particle
rho_w=62.4
```

```
rho_p=SG*rho_w//density of particle
rho_a=0.0752//density of given atmosphere,lb/ft^3
meu=1.18e-5//viscosity
K_l = D_l*(g*(rho_p-rho_a)*rho_p/(meu^2))^(1/3)//dimensionless constant
printf("\n dimensionless constant K_l=%f ",K_l);
//value of K indicates the intermediate range applies
//the settling velocity is given by
v_l=0.153*g^0.71*D_l^1.14*rho_p^0.71/(meu^0.43*rho_a^0.29)
printf("\n settling velocity v_l=%f ft/s",v_l);
H=400//vertical height blowen by particle,ft
t_l=H/v_l//descent time
v_w=20//wind velocity in miles/h
L=t_l*v_w*(5280/3600)//horizontal distance travelled by particles
printf("\n descent time t_l=%f second\n horizontal distance L=%f ft",t_l,L);
//for the minimum distance we use smallest particle
D_s=6.89e-6//diameter of smallest particle,ft
K_s=D_s*(g*(rho_p-rho_a)*rho_a/(meu^2))^(1/3)
printf("\n dimensionless constant K_s=%f ",K_s);
//velocity is in the stokes regime and is given by
v_s=g*D_s^2*rho_p/(18*meu)
printf("\n settling velocity v_s=%f ft/s",v_s);
t_s=H/v_s//descent time
L_s=t_s*v_w*(5280/3600)//horizontal distance travelled
printf("\n descent time t_s=%f s\nhorizontal distance travelled by smallest particle L_s=%f ft",t_s,L_s);
m=100*2000//mass of particles
V_act=m/rho_p//actual volume of particles
e=0.5//void fraction
V_b=V_act/e//bulk volume
printf("\ actual volume V_act=%f ft^3\nbulk volume V_b=%f ",V_act,V_b);
```

```
L_d=L_s-L//length of drop area
printf("\n L_d=%f ",L_d);
W=100//width ,ft
A_d=L_d*W//deposition area
H_d=V_b/A_d//deposition height
printf("\n deposition height H_d=%f ft",H_d);
//deposition height can be ,at bestt , described asa
    sprinkling
```

Scilab code Exa 23.8 reynolds number and terminal velocity

```
clc;
//Example 23.8
//page no 342
printf("Example 23.8 page no 342\n\n");
//a small sphere is observed to fall through caster
    oil
v_t=0.042//terminal velocity of particle
meu_f=0.9//viscosity of oil
rho_f=970//density of oil
g=9.807//grav. acc.
D_p=0.006//diameter of particle
rho_p=(18*meu_f*v_t)/(g*D_p^2)  + rho_f
printf("\n density of particle rho_p=%f kg/m^3",
    rho_p);
neu_f=9.28e-4//dynamic viscosity of fluid
R_e=D_p*v_t/neu_f//reynolds no
printf("\n reynolds no R_e=%f ",R_e);
//since R_e < 0.3
//calculation of the settling criterion factor ,K
K=D_p*(g*rho_f*(rho_p-rho_f)/(meu_f^2))^(1/3)//the
    settling criterion factor
printf("\n K=%f ",K);
//since K <3.3, stokes law applies
//the drag coeff. C_d
```

```
C_d=24/R_e
printf("\n drag coeff C_d=%f ",C_d);
F_d=3*%pi*meu_f*D_p*v_t//drag force
printf("\n drag force F_d=%f N",F_d);
F_b=(%pi/6)*D_p^3*rho_f*g//buoyancy force
printf("\n buoyancy force F_b=%f N",F_b);
//Consider the case when same sphere is dropped in
    water
rho_w=1000//density of water,kg/m^3
meu_w=0.001//viscosity of water,kg/m.s
//the particle will move faster because of the lower
     viscosity of water ,stokes law will almost
    definietly not apply
K_w=D_p*(g*rho_w*(rho_p-rho_w)/(meu_w^2))^(1/3)//the
     settling criterion factor
printf("\n k_w settling factor =%f ",K_w);
//since K_w = 158 > 43.6,the flow is in the Newton's
     law regime
//employ eq. 23.31 but include the (buoyant) density
     ratio factor
v_t_w=1.75*sqrt((rho_p-rho_w)/(rho_w)*g*D_p)//
    terminal velocity
printf("\n terminal velocity in water v_t_w=%f m/s",
    v_t_w);
```

Scilab code Exa 23.9 drag force

```
clc;
//Example 23.9
//page no 344
printf("Example 23.9 page no 344\n\n");
//the bottom of a ship,moving in water
rho=1000//density of water
v=12//velocity of boat,m/s
L=20//length,m
```

```
W=5//width ,m
meu=1e-3//viscosity
R_e=rho*v*L/meu//reynolds no
printf("Reynolds no R_e=%f ",R_e);
//from reynolds no flow is turbulent
C_d=0.031/(R_e^(1/7))//coeff. discharge\
printf("\ncoeff. discharge C_d=%f ",C_d);
//calculation of the drag on area LW
F_d=(1/2)*C_d*rho*v^2*L*W//drag force
printf("\n drag force F_d=%f N",F_d);
```

Chapter 24

sedimentation centrifugation and flotation

Scilab code Exa 24.1 terminal velocity and effective viscosity

```
clc;
//Example 24.1
//page no 350
printf("Example 24.1 page no 350\n\n");
//glass sphere are settling in water at 20 deg C
//the slurry contains 60 wt% solids
// start by assuming a basis of 100 kg of slurry
m_f=40//mass of fluid ,kg
rho_f=998//density of water ,kg/m^3
V_f=m_f/rho_f//volume of the fluid ,m^3
m_s=60//mass of solid ,kg
rho_p=2467//density of glass ,kg/m^3
V_s=m_s/rho_p//volume of glass ,m^3
V = V_f + V_s//total volume,m^3
v_frac_f = V_f/V//volume fraction for the fluid particles
printf("\n volume fraction fluid particles v_frac_f=%f ",v_frac_f);
v_frac_p=1-v_frac_f//volume fraction for the glass
```

```
particles
printf("\n volume fraction for the glass particles
    v_frac_p=%f  ",v_frac_p);
rho_m=round(v_frac_f*rho_f  + v_frac_p*rho_p)//bulk
    density of slurry
printf("\n bulk density of slurry rho_m=%f kg/m^3 ",
    rho_m);
b=10^(1.82*(1-v_frac_f))//dimensionless correction
    factor
g=9.807//gravitational acc.,m/s^2
D_p=0.0001554//diameter of particle,m
meu_f=0.001//viscosity of fluid
v_t = g*D_p^2*(rho_p-rho_f)*v_frac_f^2/(18*meu_f*b)
    //terminal velocity
printf("\n terminal velocity v_t=%f m/s",v_t);
meu_m = meu_f*b//effective mixture viscosity
printf("\n effective mixture viscosity meu_m=%f kg/m
    .s",meu_m);
```

Scilab code Exa 24.2 reynolds number

```
clc;
//Example 24.2
//page no 352
printf("Example 24.2 page no 352\n\n");
//refer to example 24.1
m_f=40//mass of fluid,kg
rho_f=998//density of water,kg/m^3
V_f=m_f/rho_f//volume of the fluid,m^3
m_s=60//mass of solid,kg
rho_p=2467//density of glass,kg/m^3
V_s=m_s/rho_p//volume of glass,m^3
V = V_f + V_s//total volume,m^3
v_frac_f = V_f/V//volume fraction for the fluid
    particles
```

```
printf("\n volume fraction fluid particles v_frac_f =%f ",v_frac_f);
v_frac_p=1-v_frac_f//volume fraction for the glass particles
printf("\n volume fraction for the glass particles v_frac_p=%f ",v_frac_p);
rho_m=round(v_frac_f*rho_f + v_frac_p*rho_p)//bulk density of slurry
printf("\n bulk density of slurry rho_m=%f kg/m^3 ",rho_m);
b=10^(1.82*(1-v_frac_f))//dimensionless correction factor
g=9.807//gravitational acc.,m/s^2
D_p=0.0001554//diameter of particle,m
meu_f=0.001//viscosity of fluid
v_t = g*D_p^2*(rho_p-rho_f)*v_frac_f^2/(18*meu_f*b) //terminal velocity
printf("\n terminal velocity v_t=%f m/s",v_t);
meu_m = meu_f*b//effective mixture viscosity
printf("\n effective mixture viscosity meu_m=%f kg/m.s",meu_m);
R_e=rho_m*v_t*D_p/(meu_m*v_frac_f)//reynolds no.
printf("\n reynolds no R_e=%f ",R_e);
```

Scilab code Exa 2.3 minimum size of charcoal

```
clc;
//Example 24.3
//page no 352
printf("Example 24.3 page no 352\n\n");
//classification of small speherical particles of charcoal with a specific gravity of 2.2
//the particles are falling in a vertical tower against a rising current of air
//we have to calculate the minimum size of charcoal
```

```
    that will settle down to the bottom of the tower
rho =0.075//density of air,lb/ft^3
meu=1.23e-5//viscosity of air,lb/ft.s
//assume stokes law to apply
SG=2.2//specific gravity of charcoal
rho_w=62.4//density of water
rho_p=SG*rho_w//density of charcoal
v=15//velocity of air
g=32.2//grav. acc
D_p1=(18*meu*v/(g*rho_p))^0.5
K1 = D_p1*(g*rho*rho_p/meu^2)^(1/3)//settling factor
printf("\n settling factor K1=%f ",K1);
//from value of K,stokes law does not apply
//therefore,assume Intermediate range law applies
D_p =((v*rho^0.29*meu^0.43)/(0.153*(g*rho_p)^0.71))
    ^(1/1.14)
printf("\n particle diameter= D_p=%f ft ",D_p);
K_n=(D_p/D_p1)*K1
printf("\n final settling factor K_n=%f",K_n)
//since the result is correct for the intermediate
    range
```

Scilab code Exa 24.4 number of Gs

```
clc;
//Exmple 24.4
//page no 354
printf("Example 24.4 page no 354\n\n");
//a particle is spining in a 3 inch ID centrifuge
r=3/12//radius of centrifuge,ft
omega=30//rotational speed,rad/s
g=32.2
G=round(r*omega^2/g)
printf("\n G=%f ",G);
```

Scilab code Exa 24.5 angular velocity

```
clc;
//Example 24.5
//page no 357
printf("Example 24.5 page no 357\n\n");
//a circular cylinder filled with water is rotated a
    uniform ,steady angular speed about it's central
    axis in rigid body motion
//since the cylinder is full the water will spill
   the moment the cylinder starts to spin ,spilling
   occur when omega > 0 rpm
// to determine the angular speed for 1/3 of the
   water to spill , consider the cylinder at rest
   when 1/3 of the water has already beem spilled
g=32.174//grav. acc
R = 0.25 //radius  of cylinder
z_st=2/3//the stationary height, ft
h = 2*(1-z_st)//increase in height is h/2,ft
omega=sqrt(4*g*(h/2)/R^2)
printf("\n omega =%f rad/s",omega);
```

Scilab code Exa 24.6 equatio describing pressure

```
clc;
//Example 26.6
//page no 392
printf("Example 26.6 page no 392\n\n");
//a bed of pulverized is to be fluidized with liquid
    oil
D=4//diameter of bed ,ft
d_p=0.00137//particle diameter ,ft
```

```
rho_s=84//coal particle density ,lb/ft^3
rho_f=55//oil density ,lb/ft^3
e_mf=0.38//void fraction
L_mf=8//bed height at minimum fluidization ,ft
P_drop=(rho_s-rho_f)*(1-e_mf)*L_mf +rho_f*L_mf
printf("\npressure drop P_drop=%f psf",P_drop);
```

Scilab code Exa 24.7 angular speed and film thickness

```
clc;
//Example 24.7
//page no 358
printf("Example 24.7 page no 358\n\n");
//a cylindrical cup open to the atmosphere is filled with liquid to a height of 7 cm
//rotated around it's axis
//calculation of an angular velocity that will cause the liquid to start spilling
h=0.03//height ,m
R=0.03//radius ,cm
//applying eq. 24.22
g=9.807//grav. acc
omega=sqrt(2*h*g/(R^2))
omega=36.2//printing mistake in book
//calculation of pressure at point A and B that is P_a and P_b
z=.1//liquid height above point A and B,m
rho=1010//density of liquid ,kg/m^3
P_a = rho*g*z
P_b=P_a//from symmetry P_a = P_b
printf("\n pressure P_a=%f Pa_gauge\n pressure P_b=%f Pa_gauge",P_a,P_b);
z_c=0.04//liquid height above point c,m
P_c=rho*g*z_c//pressure at point c
printf("\n pressure P_c=%f Pa_gauge",P_c);
```

```
//to obtain the film thicknes ,we have to find the
    original height
z_l=0.07//liquid height ,m
h_o=z_l-z_c//original height
r = 100*sqrt(2*h_o*g/(omega^2))//100 for centimeter
printf("\n r=%fcm ",r);
R=3
t_f=R-r//thikness of film
printf("\n thickness film t_f=%f m",t_f);//printing
    mistake in book
```

Scilab code Exa 24.8 velocity to obtain pure galena

```
clc;
//Example 24.8
//page no 360
printf("Example 24.7 page no 358\n\n");
//It is desired to separate quartz particles  from
    galena particles
SG_q = 2.65//specific gravity of quartz particle
SG_g=7.5//specific gravity of galena particles
rho_f=1000//density of water
rho_q=SG_q*rho_f//density of quartz paticles
rho_g=SG_g*rho_f//density of galena particle
//calculation of the settling veloctiy of the
    largest quartz particle with a diameter
D_q=9e-5//diameter of largest particle of quartz
g=9.807//grav. acc
meu_f=0.001//viscosity of water
K_q = D_q*(g*(rho_q-rho_f)*rho_f/(meu_f^2))^(1/3)//
    settling factor
printf("\n settling factor K_q=%f ",K_q);
//since K =2.27<3.3,stokes flow regime applies ,from
     the equation 23.36
v_q=g*D_q^2*(rho_q-rho_f)/(18*meu_f)//settling
```

```
velocity of thelargest quartz particle
printf("\n settling velocity (quartz) v_q=%f m/s",
    v_q);
//calculation of the settling velocity of the
    smallest galena partilce
d_g=4e-5//diameter of smallest galena particle
K_g = d_g*(g*(rho_g-rho_f)*rho_f/(meu_f^2))^(1/3)//
    settling factor
printf("\n settling factor K_g=%f ",K_g);
//since K = 1.6<3.3,stokes flow regime again applies
v_g=g*d_g^2*(rho_g-rho_f)/(18*meu_f)//settling
    velocity for galena particles
printf("\n setling velocity v_g=%f m/s",v_g);
//to  obtain pure galena the upward velociy of the
    water must be equal to or greater than the
    settling veloctiy of the quartz particle
v_w=v_q//velocity of water
printf("\n water velocity v_w=%f m/s",v_w);
```

Scilab code Exa 24.9 size range of galena particle

```
clc;
//Example 24.9
//page no 361
printf("\n Example 24.9 page no 361\n\n");
//refer to illustrative example 24.8
//we have to determine the size range of the galena
    in the top product
//to determine the size range of the galena product
    ,calculate the galena particle size that has a
    settling velocity equal to water velocity
//assume stokes law applies
v_w=0.0073//velocity of water
v_q=v_w//velocity of quartz particles
SG_q = 2.65//specific gravity of quartz particle
```

```
SG_g=7.5//specific gravity of galena particles
rho_f=1000//density of water
rho_q=SG_q*rho_f//density of quartz paticles
rho_g=SG_g*rho_f//density of galena particle
g=9.807//grav. acc
meu_f=0.001//viscosity of water
D = sqrt(18*meu_f*v_q/(g*(rho_g-rho_f)))
printf("\n diameter D =%f m",D);
//check on the validity of stokes law by calculating the K factor
K = D*(g*(rho_g-rho_f)*rho_f/(meu_f^2))^(1/3)//settling factor
printf("\n settling factor K=%f ",K);
//since K =1.82<3.3 , the flow is in the stokes law range
```

Scilab code Exa 24.10 maximum diameter

```
clc;
//Example 24.10
//page no 362
printf("Example 24.10 page no 362\n\n");
//air is being dried by bubbling through concentrated NaOH
q=4/60//flow rate of air,ft^3/min
D=2.5/12//diameter of tube
S=(%pi/4)*D^2//cross sectional area
v=q/S//velocity of air,ft/s
meu=1.23e-5//viscosity of NaOH
rho=0.0775//density of air
g=32.2//grav. acc.
SG=1.34//specific gravity of NaOH
rho_w=62.4//density of water
rho_p=SG*rho_w//density of NaOH
D_p_max = [v*(rho^0.29)*(meu^0.43)/(0.153*(g*rho_p)
```

```
    ^0.71)]^(1/1.14)//assuming that the intermediate
    range applies ,maximum diamter of particle
printf("\nD_p_max=%f ",D_p_max);
//settling factor
K=D_p_max*(g*rho*rho_p/(meu^2))^(1/3)
printf("\n settling factor K=%f ",K);
//tus result for D_p_max is correct
```

Chapter 25

porous media and packed beds

Scilab code Exa 25.1 effective particle diameter

```
clc;
//Example 25.1
//page no 370
printf("Example 25.1 page no 370\n\n");
//calculation of efffective particle diameter for a
   set of packing
V=0.2//packing volume
n=100//no. of particle assume
V_p=V*1000/n//the volume of single particle ,mm^2//
S_p=2.18//average surface area of particle ,mm^2
a_p=S_p/V_p//specific surface area of particle ,(mm)
   ^-1
D_p = 6/a_p//effective diameter of particle ,mm
printf("\n effective partcle diameter D_p=%f mm ",
   D_p);
```

Scilab code Exa 25.2 reynolds number

```
clc;
//Example 25.2
//page no 371
printf("Example 25.2 page no 371\n\n");
//refer to example 25.1
V=0.2//packing volume
n=100//no. of particle assume
V_p=V*1000/n//the volume of single particle ,mm^2//
S_p=2.18//average surface area of particle ,mm^2
a_p=S_p/V_p//specific surface area of particle ,(mm)
    ^-1
D_p = 6/a_p//effective diameter of particle ,mm
D_p=5.50//round off value for accurate answer
rho=0.235//density of fluid ,g/cm^3
meu=2e-4//viscosity ,g/cm.s
v=10//interstitial velocity ,cm
R_e=round((D_p/v)*rho*v/meu)//reynolds no
printf("\n Reynolds no R_e=%f ",R_e);
//from R_e value we can conclude that the flow of
    fluid would be in the turbulent region
```

Scilab code Exa 25.3 particle specific surface and effective diameter

```
clc;
//Example 25.3
//page no 372
printf("Example 25.3 page no 372\n\n");
//air flows across a packed bed
d_p=1.5//diamter of cylinderical particles ,cm
h=2.5//height ,cm
V_p=%pi*d_p^2*h/(4)//volume of the cylinderical
    particles
S_p=%pi*d_p*h + 2*(%pi*d_p^2/4)//cylinderical
    particle surface area ,cm^2
a_p=S_p/V_p//particle specific surface
```

```
printf("\n particle specific surface a_p =%f cm^-1 "
   ,a_p);
d_p_e=6/a_p//effective particle diameter
printf("\n effective particle diameter d_p_e=%f cm",
   d_p_e);
```

Scilab code Exa 25.4 specific surface and effective particle diameter

```
clc;
//Example 25.4
//page no 373
printf("\nExample 25.4 page no 373\n\n");
//a absorber bed consists of cube particles
L=3/4//edge length of particle
V_p=L^3//volume of particle
S_p=6*L^2//surface area of particle
a_p=6*L^2/L^3//specific particle surface area
printf("\n specific particle surface area a_p=%f in
   ^-1",a_p);
d_p_e = L//effective particle diameter = edge length
printf("\n effective particle diameter d_p_e=%f in",
   d_p_e)
```

Scilab code Exa 25.5 a catalyst tower

```
clc;
//Example 25.5
//page no 373
printf("Example 25.5 page no 373\n\n");
//gas(propane) flows through a catalyst tower
Mw=44.1//molecular weight
P=4320//pressre at the bottom of the catalyst bed,
   psf
```

```
R=10.73//gas constant
T=960//temperature,Rankine
rho=P*Mw/(R*T*144)//density of propane
L=50//height of bed,ft
D=20//diameter of bed,ft
V=%pi*D^2*L/4//bed volume
theta=10//contact time,s
e=0.4//bed porosity
q=V*e/theta//volumetric flow rate
v_s=4*q/(%pi*D^2)//superficial  velocity
printf("\n superficial velocity v_s=%f ft/s",v_s);
v_i=v_s/e//interstitial velocity
printf("\n interstitial velocity v_i=%f ft/s",v_i);
rho_s=77.28//ultimate density(spheres )
rho_b=(1-e)*rho_s//bulk density
printf("\n bulk density rho_b=%f lb/ft^3",rho_b);
d_p=0.0833//diameter of particles
a_p=6/d_p//specific surface area
printf("\n specific surface area a_p=%f ft^-1",a_p);
a_b=a_p*(1-e)//bed specific surface
printf("\n bed specific surface a_b=%f ft^-1",a_b)
```

Scilab code Exa 25.6 hydraulic radius and hydraulic diameter

```
clc;
//Example 25.6
//page no 375
printf("Example 25.6 page no 375\n\n");
//refer to example 25.5
d_p=0.0833//diameter of particles,ft
e=0.4//bed porosity
D_h=2/3*(e/(1-e))*d_p//hydraulic diameter
r_h=D_h/4//hydrulic radius
printf("\n hydraulic diameter D_h=%f ft\n hydrulic
   radius r_h=%f ft",D_h,r_h);
```

Chapter 26

fluidization

Scilab code Exa 26.2 water softner unit

```
clc;
//Example 26.2
//page no 382
printf("Example 26.2 page no 384\n\n");
//a water softner unit consists of a large diameter
   tank ,the bottom of tank is connected to a
   vertical ion exchange pipe
h_f=1.25//total fluid height
h_l=h_f
g=32.174//grav. acc
e=0.25// bed porosity
d_p=0.00417//ion exchange resin particle diameter,ft
L=1//pipe length ,ft
//assume turbulent flow ,apply burke purmer equation
v_s=sqrt(g*h_f*e^3*d_p/(1.75*(1-e)*L))//superficial
   velocity
printf("\n superficial velocity v_s=%f ft/s",v_s);
meu=6.76e-4//absolute viscosity of water
rho=62.4//density of water
//check for turbulent flow
R_e=d_p*v_s*rho/((1-e)*meu)
```

```
printf("\n R_e=%f",R_e);
//since reynold no is low the calculation is not
    valid
//assume laminar flow and use Blake-Kozeny equation
    26.9
v_s_t=rho*g*h_f*e^3*d_p^2/(150*meu*((1-e)^2)*L)//
    superficial velocity
printf("\n superficial velocity v_s_t=%f ft/s",v_s_t
    );
 //check the porous medium reynolds no
 R_e_t=v_s_t*d_p*rho/((1-e)*meu)
 printf("\n reynolds no R_e_t=%f ",R_e_t);
 //since reynolds no R_e < 10,the flow is therfor
    laminar
 D=0.167//diameter of pipe
 S=(%pi/4)*D^2//empty cross sectional area
 q=v_s_t*S//volumetric flow rate
 printf("\n vol. flow rate q=%f ft^3/s",q);
```

Scilab code Exa 26.3 pressure drop

```
clc;
//Example 26.3
//page no 384
printf("Example 26.3 page no 384\n\n");
//refer to Example 26.2
//a water softner unit consists of a large diameter
    tank ,the bottom of tank is connected to a
    vertical ion exchange pipe
h_f=1.25//total fluid height
h_l=h_f
g=32.174//grav. acc
e=0.25// bed porosity
d_p=0.00417//ion exchange resin particle diameter,ft
L=1//pipe length ,ft
```

```
//assume turbulent flow ,apply burke purmer equation
v_s=sqrt(g*h_f*e^3*d_p/(1.75*(1-e)*L))//superficial velocity
printf("\n superficial velocity v_s=%f ft/s",v_s);
meu=6.76e-4//absolute viscosity of water
rho=62.4//density of water
//check for turbulent flow
R_e=d_p*v_s*rho/((1-e)*meu)
printf("\n R_e=%f",R_e);
//since reynold no is low the calculation is not valid
//assume laminar flow and use Blake-Kozeny equation 26.9
v_s_t=rho*g*h_f*e^3*d_p^2/(150*meu*((1-e)^2)*L)//superficial velocity
printf("\n superficial velocity v_s_t=%f ft/s",v_s_t);
 //check the porous medium reynolds no
 R_e_t=v_s_t*d_p*rho/((1-e)*meu)
 printf("\n reynolds no R_e_t=%f ",R_e_t);
 //since reynolds no R_e < 10,the flow is therfor laminar
//calculation of the  pressure drop due to friction and the pressure drop across the resin bed
k=e^3*d_p^2/(150*(1-e)^2)//packed bed permeability
P_drop_fr=rho*h_f//friction pressure drop across resin bed,psf
printf("\n fricion pressure drop P_drop_fr=%f psf",P_drop_fr);
z_d=-1//length from point 2 to 3,ft
P_drop_r=rho*(z_d+h_f)//pressure drop across the resi bed
printf("\n pressure drop across across the resin bed P_drop_r=%f psf",P_drop_r);
```

Scilab code Exa 26.4 minimum fluidization

```
clc;
//Example 26.4
//page no 387
printf("\nExample 26.4 page no 387\n\n");
//air is used to fluidize a bed of speherical particles
D=0.2//bed diameter,m
d_p=7.4e-5//diameter of 200 mesh particles from table 23.2,m
rho_s=2200//ultimate solid density
rho_f=1.2//density of air
meu=1.89e-5//viscosity of air
g=9.807//grav. constant
e=0.45//bed porosity
L_mf=0.3//length at minimum fluidization
//assume laminar flow
//applying equation 26.29
v_mf=(1-e)*g*rho_s*d_p^2/(150*e^3*meu)//minimum fluidizaton veloctiy
printf("\n min. fluidization velocity v_mf=%f m/s",v_mf);
//check the flow regime
R_e=v_mf*d_p/(meu*(1-e))
printf("\n Reynolds no R_e=%f ",R_e);
//since R_e= 1.79 <10,flow is laminar
m_dot=%pi*v_mf*D^2*rho_f/4//mass flow rate
printf("\n mass flow rate m_dot =%f kg/s",m_dot);
P_fr=round((1-e)*rho_s*g*L_mf)//gas pressure drop across the bed
printf("\n gas pressure drop P_fr=%f Pa",P_fr);
```

Scilab code Exa 26.5 pressure drop in packed bed

```
clc;
//Example 26.5
//page no 389
printf("Example 26.5 page no 389\n\n");
//air  flowing through a 10 ft packed bed
V_o=4.65//superficial velocity,ft/s
meu_g=1.3e-5//viscosity of air
rho_g=0.67//density of air,lb/ft^3
e=0.89//void volume
g_c=32.2//grav. constant
L=10//length of packed bed
d_p=0.007815//effective particle diameter
P_drop = [(150*V_o*meu_g/(g_c*d_p^2))*((1-e)^2/e^3)
   + (1.75*rho_g*V_o^2/(g_c*d_p))*((1-e)^2/e^3)]*L//
   pressure drop
printf("\n pressure drop P_rop=%f lb/ft^2",P_drop);
   //calculation error in book
```

Scilab code Exa 26.6 a bed of pulverized coal

```
clc;
//Example 26.6
//page no 392
printf("Example 26.6 page no 392\n\n");
//a bed of pulverized is to be fluidized with liquid
    oil
D=4//diameter of bed ,ft
d_p=0.00137//particle diameter ,ft
rho_s=84//coal particle density ,lb/ft^3
rho_f=55//oil density,lb/ft^3
e_mf=0.38//void fraction
L_mf=8//bed height at minimum fluidization,ft
P_drop=(rho_s-rho_f)*(1-e_mf)*L_mf +rho_f*L_mf
printf("\npressure drop P_drop=%f psf",P_drop);
```

Scilab code Exa 26.7 volumetric flow rate

```
clc;
//Example 26.7
//page no 393
printf("Example 26.7 page no 393\n\n");
//refer to example 26.6
D=4//diameter of bed ,ft
d_p=0.00137//particle diameter ,ft
rho_s=84//coal particle density ,lb/ft^3
rho_f=55//oil density ,lb/ft^3
meu_f=3.13e-4//viscosity of oil
e_mf=0.38//void fraction
L_mf=8//bed height at minimum fluidization ,ft
L_f=10//bed height ,ft
e=1-L_mf*(1-e_mf)/L_f//bed voidage
g=32.174//grav acc
v_s=(d_p^2)*g*(e^3)*(rho_s-rho_f)/(150*meu_f*(1-e))
    //superficial velocity
printf("\n superficial velocity v_s=%f ft/s",v_s);
q=(%pi/4)*D^2*v_s//volumetric flow rate
printf("\n vol. floe rate q=%f ft^3/s",q);
//check on the laminar flow assumption
meu_f=0.01
R_e=d_p*v_s*rho_f/(meu_f*(1-e))
printf("\n reynolds no R_e=%f",R_e);
printf("\n since R_e is less than 10 ,flow is
    laminar");
```

Scilab code Exa 26.8 friction factor and permeability of the catalyst

```
clc;
```

```
//Example 26.8
//page no 393
printf(" Example 26.8 page no 393\n\n");
//refer to example 25.6
//obtain the porous medium friction factor usingthe burke -plummer equation
///since the flow is turbulent ,eq.26.6 applies
f_pm=1.75//porous medium friction facot
v_s=2//superficial velocity
e=.4//porosity
L=50//length of bed
d_p=0.0833//particle diameter
g=32.174//grav. acc
h_f=(f_pm)*(v_s^2)*(1-e)*L/(g*(e^3)*d_p)//head loss
printf("\n head loss h_f=%f ft of propane ",h_f);
//applying bernoulli eq. between the entrance and gas exit
//neglect the dynamic head
P2=4320//pressure at the bottom of the catalyst bed
rho_f=0.0128//density of fluid
z_d=-50//length from point 2 to 3,z2-z1
P1 = P2 + rho_f*(z_d-h_f)// absolute pressure of the inlet gas
printf("\n pressure P1=%f psf",P1);
//since flow is turbulent , permeablity of the medium k can not be calculated
```

Scilab code Exa 26.9 activated carbon bed

```
clc;
//Example 26.9
//page no 394
printf("Example 26.9 page no 394\n\n");
//turbulent flow of water through a carbon bed
d_p=0.001//particle diameter
```

```
meu=0.001//viscosity of water
e=0.25//porosity
R_e=1000//R_e is >1000 for turbulent flow ,for
    minimum pressure drop
rho=1000//density of water ,kg/m^3
v_s=R_e*meu*(1-e)/(d_p*rho)//superficial velocity
printf("\n superficial velocity v_s=%f m/s",v_s);
phi_s=1//spehercity
L=0.5//length of bed ,m
P_drop = 1.75*rho*L*v_s^2*(1-e)/(phi_s*d_p*(e^3))//
    presssure drop
printf("\npressure drop P_drop=%f Pa",P_drop);
```

Scilab code Exa 26.10 bed height and porosity

```
clc;
//Example 26.10
//page no 395
printf("Example 26.10 page no 395\n\n");
//a bed of 200 mesh particles is fluidized with air
d_b=0.2//diameter of bed ,m
d_p=7.4e-5//particle diameter
L_mf=0.3//bed height at minimum fludization
e_mf=0.45//bed porosity at min. fluidization
L_o=L_mf*(1-e_mf)//the zero porosity bed height
printf("\n zero porosity bed height L_o=%f m",L_o);
rho_s=2200//density of particles
rho_f=1.2//density of fluid
g=9.807//grav. acc
meu_f=1.89e-5//viscosity of fluid
//assuming laminar flow ,use equation 26.9
v_mf =(e_mf^3)*(g*(rho_s-rho_f)*(d_p^2))/(150*(1-
    e_mf)*meu_f)//velocity at minimum fluidization
printf("\n velocity at min. fluidization v_mf=%f m/s
    ",v_mf);
```

```
v_t=0.35//terminal velocity from example 26.3
e=0.91//value of e porosity from eq26.9
L_f=L_o/(1-e)//expanded bed height L_f
m=rho_s*%pi*d_b^2*L_o//bed inventory
printf("\n expanded bed height L_f=%f m\n bed
   inventory m=%f kg",L_f,m);
```

Scilab code Exa 26.11 fluidization mode

```
clc;
//Example 26.11
//page no 396
printf("\n Example 26.11 page no 396\n\n");
//refer to illustrative example 26.9
d_p=7.4e-5//particle diameter
L_mf=0.3//bed height at minimum fludization
e_mf=0.45//bed porosity at min. fluidization
L_o=L_mf*(1-e_mf)//the zero porosity bed height
printf("\n zero porosity bed height L_o=%f m",L_o);
rho_s=2200//density of particles
rho_f=1.2//density of fluid
g=9.807//grav. acc
meu_f=1.89e-5//viscosity of fluid
//assuming laminar flow ,use equation  26.9
v_mf =(e_mf^3)*(g*(rho_s-rho_f)*(d_p^2))/(150*(1-
   e_mf)*meu_f)//velocity at minimum fluidization
printf("\n velocity at min. fluidization v_mf=%f m/s
   ",v_mf);
F_mf=v_mf^2/(g*d_p)//fluidization mode
printf("\n fluidization mode F_mf=%f ",F_mf);
//from value of F_mf ,fluidization is smoth,F_mf
   =0.66<0.13
```

Chapter 27

filteraion

Scilab code Exa 27.2 a plate and frame filter press

```
clc;
//Example 27.2
//page no 413
printf("Example 27.2 page no 413\n\n");
//plate and frame filter press is to be employed to
    filter a slurry
m_dot_slurry=600*60//mass flow rate ,lb/h
m=0.1//sluury contain 10% by mass solid
m_dot_solids = m*m_dot_slurry//the solid flow rate
    in the slurry
a=(1/5)//filter colth area required for 1 lb/h of
    solid
A=m_dot_solids*(a)//filter colth area for 3600 lb/h
    of solids
printf("\n filter colth area A=%f ft^2",A);
```

Scilab code Exa 27.4 press and filter plate

```
clc;
//Example 27.4
//page no 414
printf("Example 27.4 page no. 414\n\n");
m=1947//slope of curve b/w t/V vs V,s/ft^6
K_c=2*m
c=217//intercept on graph
q_r=c//reciprocal of q
printf("\n coeff. K_c=%f s/ft^6\n coeff. q_r=%f s/ft
    ^3",K_c,q_r)
```

Scilab code Exa 27.5 filtration coefficients

```
clc;
//Example 27.5
//page no 415
printf("Example 27.5 page no 415\n\n");
//refer to example 27.4
meu=5.95e-4//viscosity
g_c=32.174//grav. acc
P_drop=20*144//pressure drop
q_o=(1/217)//flow rate
S=0.35//filteration area per unit
K_c=3894//coefficentc
c=4.142//slurry conentration
R_m=S*g_c*P_drop/(q_o*meu)//filteration coeff.
printf("R_m=%f ft",R_m);
alpha=K_c*S^2*g_c*P_drop/(c*meu)//filteration coeff.
printf("\n alpha=%f ft/lb",alpha);
```

Scilab code Exa 27.7 filtration experiment

```
clc;
```

```
//Example 27.7
//page no 418
printf("Example 27.7 page no 418\n\n");
//the following result were obtained during the running of a filteration experiment
alpha=4.57e+11//cake resistance,ft/lb
P_drop=1554//pressure drop ,lbf/ft^2
alpha_o=alpha/(P_drop^0.21)//specific cake resistance
printf("\n specific cake resistance alpha_o=%f ft/lb",alpha_o);
```

Scilab code Exa 27.9 filter press capacity

```
clc;
//Example 27.9
//page no 418
printf("Example 27.9 page no 418\n\n");
//a filter press operates at a constant pressure
P=50//pressure,psig
q=10//flow rate,ft^3/min
//applying eq.27.12
//q = P/(B*V_s + C)
//in this case,V_s=0
C=P/q//constant
//for constant pressure applying equation 27.13
//t = B*V_s^2/(2P) + C*V_s/P
t=60//time ,min
V_s=100//volume,ft^3
B= 2*P*t/(V_s^2) - 2*C/V_s//constant
//during the washing cycle t_w = V_w/q_w
//B and C remain same
V_w=15//volume of water for washing per hr
t_w= V_w*(B*V_s + C)/P//time in washing
printf("\n washing time t_w=%f min",t_w);
```

```
t_d=30//time for dumping and cleanig
t_c=(t + t_w +t_d)/60//collecting time,in hr
q_c =V_s/t_c//flow rate for 100 ft^3
printf("\n flow rate q_c=%f gal/hr ",q_c);
```

Chapter 28

environmental management

Scilab code Exa 28.3 cement dust emitting source

```
clc;
//Example 28.3
//page no 430
printf("Example 28.3 page no 430\n\n");
//we have to determine the minimum distance
   downstream from a cement dust emitting  source
   that will be free of cement deposit
//the souce is equipped with a cyclone located 150
   ft above ground level
//neglect meteorological aspects
h=150//cyclone height from ground level,ft
v_w=3/3600//wind velocity,miles/second
SG=1.96//specific gravity of cement dust
rho_w=62.4//density of water,lb/ft^3
rho_p=SG*rho_w///density cement particles
//applying ideal gas law for density of air
P=1//pressure,atm
M= 29//mol. weight of air
R=0.73//gas constant
T=520//temperature,Rankine
rho_a=P*M/(R*T)//density of air
```

```
meu=1.22e-5//viscosity of air,lb/ft.s
g=32.174//grav. acc.
d_p=2.5/(25400*12)//particle diameter,ft
K = d_p*(g*rho_p*rho_a/(meu^2))^(1/3)//settling
    factor
printf("\n settling factor K=%f ",K);
//since K=0.103<3.3,sokes law rane applies
v= g*d_p^2*rho_p/(18*meu)//terminal settling
    velocity)
printf("\nsettling velocity v=%f ft/s",v);
t=h/v//time for desent
printf("\n desent time t=%f sec",t);
x=v_w*t//horizontal distance travelled in miles
printf("\n minimum horizontal distance x=%f miles",x
   );//printing mistake in book
```

Scilab code Exa 28.4 filter system

```
clc;
//Example 28.4
//page no 432
printf("Example 28.4 page no 432\n\n");
//it is proposed to install a pulse jet fabric
    filter system to clean an air stream containing
    particulate pollutants
//we have to select the most apporpriate filter beg
    fabric
q_scfm=10000//volumetric flow rate of polluted air
   stream at 60 deg F ,1 atm
T=520//temperature,R
T_o=710//operating temparature ,R
q_acfm=q_scfm*(T_o/T)//flow rate in acfm
v_f=2.5//filteration velocity,ft/min
S_c=q_acfm/v_f//filtering beg area
printf("\n filtering beg area S_c=%f ft^2",S_c);
```

```
//(1) for bag A ,the area and N number of bags are
D_a=8/12//diamter,ft
H_a=16//height,ft
S_a =%pi*D_a*H_a//area
N_a= round(S_c/S_a)//no. of bags
printf("\n area S_a=%f ft^2\n number og bags N_a=%f ",S_a,N_a);
//(2) for bag B
D_b=10/12//diameter,ft
H_b=16//height,ft
S_b=%pi*D_b*H_b//area
N_b=round(S_c/S_b)//no. of bags
printf("\n area S_b=%f ft^2\n no. of bags N_b=%f ",S_b,N_b);
//total cost for each bag
//for bag A
c_a=26//cost per bag
TC_a=round(N_a*c_a)//total cost for A bag
printf("\n total cost TC_a=%f $",TC_a);
//for bag B
c_b=38//cost per bag
TC_b=N_b*c_b//total cost for bag B
printf("\n total cost TC_b=%f $",TC_b);
//since the total cost for bag A is less than bag B, select bag A
```

Scilab code Exa 28.5 fabric system

```
clc;
//Example 28.5
//page no 433
printf("\n Example 28.5 page no 433\n\n");
//we have to determine the number if filtering bags required and cleaning frequency for a plant equipped with a fabric system
```

```
q=50000//volumetric flow rate of gas stream,acfm
v_f=10//filteration velocity,ft/min
D=1//diameter of filtering bag,ft
L=15//length of filtering bag,ft
S_c=q/v_f//filtering area,ft^2
S=%pi*D*L//area per bag,ft^2
N=S_c/S//no. of bags
printf("\n no. of bags N=%f ",N);
c=0.0007143//dust concentration ,lb/ft^2
P_drop=8//pressure drop ,in H20
t=(P_drop-(0.2*v_f))/(5*c*v_f^2)//time sic ethe bags
    were cleaned
printf("\n time t=%f min",t);
```

Scilab code Exa 28.6 manning equation

```
clc;
//Example 28.6
//page no 434
printf("Example 28.6 page no 434\n\n");
//comparison between flow in pipes and open channel
    flow
//water is passing through a trapezodial channel
l_b=20//length of bottom base,ft
l_t=50//length of top base,ft
h=7.5//height of channel,ft
A = (l_b+ l_t)*(h/2)//cross sectional area
P = l_b +sqrt(h^2+ (2*h)^2)//perimeter of trapezoid
r_h=A/P//hydrulic radius
S=0.0008//coeff. in manning equation
n=0.02//coeff. in manning eq.
q = 1.486*A*r_h^(2/3)*S^(1/2)/n//manning equation to
    determine flow rate
printf("\n volumetric flow rate q=%f ft^3/s",q);
```

Scilab code Exa 28.7 a watershed

```
clc;
//Example 28.7
//page no 435
printf("\n Example 28.7 page no 435\n\n")
//waste water treatment plant
//we have  to compare the total nitrogen discharge
   from the watershed with that of the city 's
   sewage treatment plant
q_w=10//flow rate from waste water treatment plant
c=35//nitoren concentration ,mg/l
m_dot_w=c*q_w*8.34//discharge  from the treatment
   plant
printf("\n fdischarge from the treatment plant
   m_dot_w=%f lb/day",m_dot_w);
S=8//area of watershed ,mi^2
r=0.06//rate of rainfall ,ml/day
n=.5//50% rain reaches the sewers
q=n*r*S*(5280^2/(3600*12))//volumetric flow rate of
   the runoff
c_r=9//tota; nitrogen conentration in runoff ,mg/l
rho=62.4///density of water
m_r=q*c_r*1e-6*(3600*24)*rho//total nitrogen
   discharge  from runoff
printf("\n total nitrogen discharge m_r=%f lb/day ",
   m_r);
 //since the durinf rain ,the runoff is over 2.5
    times that for the tratment plant
```

Scilab code Exa 28.8 aerobic digester

```
clc;
//Example 28.8
//page no 436
printf("Example 28.8 page no 436\n\n");
//we have to determine the siaze an aerobic digester to treat the solids
m=1000//mass of solid that is generate by municipality,lb
OL=0.2//organic loading,lbcs/ft^3.day
VS=.78//volatile solids
V_ol=m*VS/OL//volume based on organic loading
printf("\n volume based on organic loading V_ol=%f ft^3",V_ol);
t_h=20//detention time hydraulic, days
TS=0.044//percentage solids enterning digester
V_hl=m*t_h/(TS*8.33*7.48)//volume based on hydrulic load
printf("\n volume based on hyraulic load V_hl=%f ft^3",V_hl);
//since V_hl >V_ol,the hdraulic time controls and the design volume is V_hl
```

Scilab code Exa 28.9 deep cavern

```
clc;
//Example 28.9
//page no 437
printf("Example 28.9 page no 437\n\n");
//a large deep cavern has been proposed as an ultimate disposal site for both solid hazardous and municipal wastes
V_c=0.78//approximate total volume of cavern,mi^2
V_s=.75//% volume availiable for solid waste depositry
V=V_c*V_s*(5280)^3//volume of the cavern availible
```

```
   for the solid waste ,factor 5280 to convert mi^3
   into ft^3
printf("\n volume of cavern availible for solid
   waste V=%f ft^3",V)
r=20000//proposed maximum waste feed rate to cavern
   ,lb/day
rho=30//average bulk density,lb/ft^3
q=(r/rho)*(6*52)//volume rate of solid deposited
   within the cavern in ft^3/year
printf("\n q=%f ",q);
t=V/q//time to fill the cavern
printf("\n time to fill the cavern t=%f year",t);
```

Scilab code Exa 28.10 compliance stack test

```
clc;
//Example 28.10
//page no 438
printf("Example 28.10 page no 438\n\n");
// a compliance stack test on a facility yields the
   results ,we have to determine whether the
   incineratormeets the state particulate standard
   of 0.05 gr/dscf
g=9.807//grav. acc
rho_l=1000//density of manometer fluid,kg/m^3
rho=1.084//density of flue gas,kg/m^3
C=0.85//pitot tube constant
h=0.3772//mean pitot tube reading ,in H2O
m=0.16//mass of particulate collected ,g
V=35//volume sampled,dscf
C_p=m*15.43/V//partculate concentration,gr/dscf
printf("\n particulate con. C_p=%f gr/dscf",C_p);
//since this does not exceed the particulate
   standard of 0.05 gr/dscf,the facility is not in
   compliance
```

```
//the stack flow rate is calculated from the velocity measurement
v=C*sqrt(2*g*(rho_l/rho)* 0.0254*h)/.3048//velocity
printf("\n velocity v=%f fps",v);
D=2//diameter of stack,ft
v_s=(v*%pi*D^2/4)*60//stack flow rate
printf("\n stack flow rate v_s=%f acfm",v_s);
w_mo=0.07//% moisture in stack gas
v_dry=(1-w_mo)*v_s//dry volumetric flow rate
//correct to standard conditions of 70 deg F and 1 atm
T_s=530// standard temprature deg R
P_s=29.9//standard pressure,psi
P_g=29.6//pressure of stack gas,psi
T_g=600//temprature of standard gas,deg R
q_s=v_dry*(T_s/T_g)*(P_g/P_s)//standard volumetric flow rate
printf("\n standard volumetric flow rate q_s=%f dscfm",q_s)
R_e=C_p*q_s*(1440/7000)//particulate emission rate
printf("\n particulate emmision rate R_e=%f lb/day",R_e);
w_co2=0.14//percentage of co2 by volume
w_N2=0.79//percentage of N2 by volume
mw_o=32//molecular weight of oxygen
mw_co2=44//molecular weight of co2
mw_N2=28//molecular weight of N2
MW_d=w_mo*mw_o + w_co2*mw_co2 +w_N2*mw_N2//molecular weight of flue gas on dry basis
printf("\n mol. weight of flue gas on dry basis MW_d=%f lb/lbmol",MW_d);
```

Chapter 29

aaccident and emergency

Scilab code Exa 29.2 probability distribution

```
clc;
//Example 29.2
//page no 455
printf("Example 29.2 page no 455\n\n");
//the probability distribution of the number of
    defectives in a sample of five pump drawn with
    replacement from lot of 1000 pump
//the probability distribution of x, thenumber of
    sucess in n performances of th erandom experiment
     is the probability distribution function
//P(x) = (factorial(n)/factorial(x)*(factorial n -
    factorial x))*(p^x*q^n-x)
n=5//no. of performances
x=3//no. of successes
p=0.05//probability of sucesses when the sample of
    pump is drawn with replacement
q=1-p//probability of faliure
P=factorial(n)*((p^x)*(q^(n-x)))/(factorial(x)*(
    factorial(n)-factorial(x)))//probability when x
    =3//probability when x=3/factorial(x)*(factorial(
    n)-factorial(x))*(p^x*q^(n-x))//probability when
```

```
x=3
printf("\n probability P=%f  ",P); //calculation error in book
```

Scilab code Exa 29.3 an iron foundry

```
clc;
//Examctple 29.3
//page no 455
printf("Example 29.3 page no 455");
//an iron foundry has four work stations that are connected to single duct
v_air=4000//the minimum air velocity required for general foundry dust,ft/min
v_air_s=v_air/60//velocity of air in ft/s
n=4//no. of duct
q_e=3000//each duct transport air,acfm
q=n*q_e//total transport,acfm
A=q/v_air//cross sectional area required ,ft^2
D=sqrt(4*A/%pi)//duct diameter,ft
rho=0.075//density of air
meu=1.21e-5//viscosity of air
R_e=D*rho*v_air_s/meu//reynolds no
printf("\n reynolds no. R_e=%f ",R_e);
f=0.003///fanning friction factor,since R_e >20000
L=400//duct length
g_c=32.2//grav. acc.
P_drop_d=(4*f*L*v_air_s^2*rho)/(2*g_c*D)//pressure drop in the duct
printf("\n pressure drop in duct P_drop_d=%f lbf/ft^2",P_drop_d);
P_drop_h=0.5*5.2//pressure drop in  hood
P_drop_cyc=3.5*5.2//pressure drop in cyclone cleaner
P_drop_t=P_drop_d + P_drop_h + P_drop_cyc//total prssure drop
```

```
printf("\n total pressure drop P_drop_t=%f lbf/ft^2"
    ,P_drop_t);
neta=0.4//pump efficiency
hp=(P_drop_t*q/neta)*3.03e-5//power required in hp
printf("\n power required hp=%f hp ",hp);
```

Scilab code Exa 29.6 a baghouse

```
clc;
//Example 29.6
//page no 458
printf("Example 29.6 page no 458\n\n");
//a baghouse has been used to clean a particulate
    gas steam
l_i=5//inlet loading,grains/ft^3
l_o=0.03//outlet loading,grains/ft^3
l_o_max=0.4//maximum outlet loading,grains/ft^3
E_b=(l_i-l_o)/l_i//efficiency before bag failure
P_t=1-E_b//penetration before bag failure
E=(l_i-l_o_max)/l_i//efficiency on regulatory
    conditions
P_t_r=1-E//penetration regulatory conditons
P_tc=P_t_r-P_t//penetration associated with failed
    bags
printf("\n penetration associated with failed bags
    P_tc=%f ",P_tc);
P_drop=6//pressure drop,in of H2O
T=250//temperature,deg F
q=50000//volumetric flow rate,acfm
D=8//diamter of bags,in
L= q*P_tc/(0.582*P_drop^0.5*D^2*(T+460)^0.5)//number
     of bag failure that the system can tolerate and
     still remain in compliance
printf("\n no. of bags L=%f ",L);
//thus if two bags fail,baghouse is out of complance
```

Scilab code Exa 29.7 a cstr type reactor

```
clc;
//Example 29.7
//page no 461
printf("\Example 29.7 page no 461\n\n");
//a reactor is located in a relatively large laboratory ,the reactor  can emit as much as of hydrocarbon into the room if a safety valves ruptures
v=1100//volume of reactor ,m^3
T=295//temperature of reactor ,K
v_s=0.0224//volume of gas at STP,m^3
T_s=273//standard temperature ,K
n_air=(v/v_s)*(T_s/T)//total gmoles of air in the room
printf("\n n_air=%f gmol",n_air);
v_r=0.75//Hydrocarbon emit by reactor ,gmol
x_hc= (v_r/(n_air + v_r))*10^9//mole fraction of hydrocarbon in the room,parts per billion
printf("\n mole fraction of HC x_hc=%f ppb ",x_hc);
```

Chapter 31

numerical methods

Scilab code Exa 31.1 linear algebraic equation

```
clc;
//Example 31.1 page no 486
printf("Example 31.1 page no 486\n\n ");
//set of linear algebric equation using gauss
   elimination
A=[3,-2,1;1,4,-2;2,-3,-4]//matrix A
B=[7;21;9]//matrix B
X=inv(A)*B
printf("\n X=%f",X);
X1=X(1,1)//value of X1
X2=X(2,1)//value of X2
X3=X(3,1)//value of X3
printf("\n X1=%f\nX2=%f \nX3=%f",X1,X2,X3);
```

Scilab code Exa 31.2 temperature and pressure

```
clc;
//Example 31.2
```

```
//page no 492
printf("Example 31.2 page no 492\n\n");
//the vapor pressure p' for a new synthetic chemical at a given temperature
t1=1100//assume intial actual temperature,k
T1=t1*1e-3//temperature,k
printf("\n T1=%f k",T1);
f1=T1^3 -2*T1^2 + 2*T1 -1//function of T,f(T)
f_d1=3*T1^2 -4*T1 + 2//derivative of f(T)
//using newton rapson formula to estimate T2
T2=T1 -(f1/f_d1)//temperature T2
printf("\n T2=%f k",T2);
f2=T2^3 -2*T2^2 + 2*T2 -1
f_d2=3*T2^2 -4*T2 + 2
T3=T2 -(f2/f_d2)//temperature T3
printf("\n T3=%f k",T3);
//finally the best estimate is T3,t=1.000095
```

Scilab code Exa 31.3 newton rapson method

```
clc;
//Example 31.3
//page no 493
printf("Example 31.3 page no 493\n\n");
//friction factor for smooth tubes can be approximated by
//f = 0.079*R_e^(-1/4),if 2000< R_e<2e-5
// average velocity in the system ,involving the flow of water at 60 deg F is given by
//v =sqrt(2180/(213.4R_e^(-1/4) + 10), flow of water at 60 deg F
//R_e=12168v,putting this value and by simplifying we get
v=poly(0,'v');
f=213.5*v^2 +105.03*v- 22896.08*v
```

```
//df=derivat(213.5*v^2 +105.03*v- 22896.08*v)
df=- 22791.05 + 427*v
v1=5
f1=213.5*v1^2 +105.03*v1- 22896.08*v1// value of f
    at v=5
df1=- 22791.05 + 427*v1//value of df at v=5
v2=v1-(f1/df1)
//by iteration we get values of v3,v4,v5,v6
//at v6 result converges
v6=10.09
printf("\n v6=%f ft/s ",v6);
```

Scilab code Exa 31.4 simpson rule

```
clc;
//Example 31.4
//page no 497
printf("Example 31.4 page no 497\n\n")
//integration
I=integrate('(1-0.4*x^2)/((1-x)*(1-0.4*x)-1.19*x^2)'
    ,'x',0,0.468)
printf("\n I=%f ",I);
```

Chapter 32

economics and finance

Scilab code Exa 32.5 fluid transportation

```
clc;
//Example 32.5
//page no 512
printf("Example 32.5 page no 512\n\n");
// a fluid is transported 4 miles under turbulent
   flow conditions
//we have two choices in designing the system
OC_a=20000//per year pressure drop costs for the 2
   inch ID pipe,$
CRF=0.1//capital recovery factor for both pipe
OC_b=OC_a/16//operating cost associated with the
   pressure drop cost per year for 4 inch pipe
d=4*5280//distance,feet
c_a=1// 2 inch ID pipe cost per feet,$
c_b=6// 4 inch ID pipe cost per feet,$
CC_a=d*c_a*CRF//capital cost for  2 inch ID pipe,$
CC_b=d*c_b*CRF//capital cost for 4 inch ID pipe,$
TC_a= OC_a +CC_a//total cost associated with 2 inch
   pipe
printf("\n total cost with 2 inch pipe TC_a=%f $",
   TC_a);
```

```
TC_b=OC_b + CC_b//total cost associated with 4 inch pipe
printf("\n total cost with 4 inch pipe TC_b=%f $",TC_b);
//from result we can conclude that 4 inch pipe is more economical
```

Scilab code Exa 32.6 particulate control device

```
clc;
//Example 32.6
//page no 512
printf(" Example 32.6 page no 512\n\n")
//a process emits gas of containg dust,a particulate device is employed for particle capture
q=50000//vol. flow rate of dust,ft^3/min
c=2/7000//inlet loading of dust
DV=0.03//value of dust
//recovered value RV can be expressed in terms of pressure drop
//RV=q*c*DV*P1/(P1+15)
C_e=0.18//cost of electricity
E_f=0.55//fractional efficiency
function x=f(P1)

    E=P1/(P1+15)//collection efficiency
    RV=q*c*DV*E//recovered value in terms of E$/min
    C_p=q*(C_e/44200)*P1/(E_f*60)
//  x=q*c*DV*P1/(P1+15)-q*C_e*P1/E_f
    x=RV-C_p
endfunction
P1=fsolve(100,f)
printf("\n P1=%f",P1);
//calculation mistake in book
```

Scilab code Exa 32.8 a filter press

```
clc;
//Example 32.8
//page no 514
printf("Example 32.8 page no 514\n\n");
//a filter press is in operation
//we have to determine the appraisal value of the
    press
i=0.03375//intrest on fund
n=9//time,year
SFDF=i/((1+i)^n -1)//sinking fund depreciation
    factor
P=60000//cost of filter press,$
L=500//salvage value,$
UAP= (P-L)*SFDF//uniform annual payment,$
printf("\n uniform annual payment UAP=%f $",UAP);
//in determing the appraisel value where the
    straight line method of depreciation is used
// B = P -(P-L/n)x
//where x refers to any time the present before the
    end of usable
x=5//let for 5 year
B5=P-((P-L)/n)*x//appraissl value for 5 year
printf("\n apprasial value B=%f $",B5);
```

Scilab code Exa 32.9 an outdated environmental control device

```
clc;
//Example 32.9
//page no 516
printf("Example 32.9 page no 516\n\n");
```

```
//we have to determine the annulized cost of a new
    processing plant of enviromental control
//input data
CC=150000//capital cost,$
I=.07//interst
n=5//time,year
CRF=(I*(1+I)^n)/((1+I)^5-1)//capital recovery factor
    CRF
IC=CRF*CC//installation cost,$
OC=15000//operation cost,$
AC=IC + OC//annulized cost
printf("\n annulized cost AC=%f $",AC);
```

Chapter 33

biomedical engineering

Scilab code Exa 33.1 viscosity of plasma

```
clc;
//Example 33.1 page no 524
printf("Example 33.1 page no 524\n\n")
//unit conversion of viscosity of blood
meu_cp=1.25//vicosity of blood in cp
meu_e=meu_cp*6.72e-4//viscosity in english unit,lb/
    ft.s
printf("\n viscosity meu_e=%f lb/ft.s",meu_e)
```

Scilab code Exa 33.2 pressure units

```
clc;
//Example 33.2 page no 525
printf("Example 33.2 page no 525\n\n");
//unit conversion of poressure given in mmHg into
    various units
P=80//pressure given in mmHg
P1=P*(29.92/760)//pressure , in Hg
```

```
P2=P*(33.91/760)//pressure ,ft H2O
P3=P2*12//pressure ,in H2O
P4=P*(14.7/760)//pressure ,psia
P5=P*(2116/760)//pressure ,psfa
P6=P*(1.013e+5/760)//pressure ,N/m^2
printf("\n P1=%f inHg\n P2=%f ft H2O\nP3=%f in H2O\n
    P4=%f psia\nP5=%f psfa\nP6=%f N/m^2",P1,P2,P3,P4
    ,P5,P6);//in book answers are round off after
    decimal but there are exact answers
```

Scilab code Exa 33.5 artery branches

```
clc;
//Example 33.5 page no 527
printf("Example 33.5 page no 527\n\n");
//an artery branches into two smaller equal area
    arteries so that velocity is same
//because q1=q2,volumetric flow rate
//q1=q2=q/2
//because s1=s2,cross sectional area
//s1=s2=s/2
//let the values
q=1//flow rate at inlet artery
q1=q/2//flow rate at outlet artery
s=1//area of inlet artery
s1=s/2//area of outlet artery
//v=q/s
D_r=sqrt(q/q1)//ratio of diameters
printf("\n ratio of diameters D_r=%f ",D_r);
```

Scilab code Exa 33.6 a blood vessel

```
clc;
```

```
//Example 33.6
//page no 528
printf("Example 33.6 page no 528\n\n");
//a blood vessel branches into three openings
//we have to find the velocity in 3 rd opening
a=0.2//cross sectional area of inlet 1,m^2
v=5//velocity inlet 1,mm/s
a1=0.08//area of branch1,m^2
v1=7//velocity in branch2,mm/s
a2=0.025//area of branch,m^2
v2=12//velocity in branch,mm/s
a3=0.031//area of branch,m^2
q=a*v//flow rate at inlet
q1=a1*v1//flow rate at branch 1
q2=a2*v2//flow rate at branch 2
q3=q-q1-q2//flow rate in branch 3
v3=q3/a3//velocity in branch 3
printf("\n velocity v3=%f mm/s",v3);
```

Scilab code Exa 33.7 average velocity of blood

```
clc;
//Example 33.7
//page no 531
printf("Example 33.7 page no 531\n\n");
//blood flowing through the arota
D=2.5//diameter of arota
S=%pi*D^2/4//cross sectional area,cm^2
q=93.3//volumeric flow rate,cm^3/s
v=q/S//flow velocity
printf("\n flow velocity v=%f cm/s",v);
```

Scilab code Exa 33.8 heart beat

```
clc;
//Example 33.8
//page no 531
printf("Example 33.8 page no 531\n\n");
//one of the auther of this book is 74 year old ,we
   have to determine the no. of times that the the
   auther's heart has to beat to date
Y=74//age in year
d=365//days
h=24//hours
m=60//minutes
b=80//heart beats per minutes
T=Y*d*h*m*b// no. of times heart beats
printf("\n no.of times heart beats T=%f ",T);
```

Scilab code Exa 33.9 volume of blood

```
clc;
//Example 33.9
//page no 531
printf("\n Example 33.9 page no 531\n\n");
//refer to example no 33.8
Y=74//age in year
d=365//days
h=24//hours
m=60//minutes
b=80//heart beats per minutes
T=Y*d*h*m*b// no. of times heart beats
v=70//volume of blood discharge with  each blood,ml
V=T*v//volume of blood that has circulated through
   the auther's system over his lifetime
printf("\n Volume of blood  V=%f ml",V);
```

Scilab code Exa 33.10 minimum pressure drop

```
clc;
//Example 33.10
//page no 532
printf("Example 33.10 page no 532\n\n");
//the flow of blood from the arota to the atrium is
   reprsented by a vessel
meu=1.1*6.72e-4//viscosity of blood
L=0.3//length of vessel,mile
g_c=32.2//grav. acc
rho=62.4//density of blood
D=2.53/30.48//diameter of vessel,ft
P_drop=32*meu*(19/30.48)*5280*L/(rho*D^2*g_c)
printf("\n pressure drop P_drop=%f ft*lbf/lb",P_drop
   )
//snice the model is resonable from the fluid
   dynamics perspective
```

Scilab code Exa 33.12 power generated by heart

```
clc;
//Example 33.12
//page no 534
printf("\n Example 33.12 page no 534\n\n")
//estimation of power generated by human heart
P_drop=60//pressure drop in the circulatory system,
   mmHg
q=0.0033//volumetric flow rate,ft^3/s
hp=(q*P_drop*14.7*(144/760))//power generated
printf("\npower generated hp=%f hp",hp);//
   calculation error in book
```

Chapter 34

open ended problems

Scilab code Exa 34.4 a moving gas stream

```
clc;
//Example 34.4 page no 548
printf("Example 34.4 page no 548\n\n");
//a gas stream is discharged through a stack
m_dot =10000//mass flow ratein acfm
v=50//velcoity in  ft/s
KE=m_dot*v^2*(29/(379*32.2*60))//others are
   conversion factor for unit
printf("\n KE=%f ft.lbf/s",KE);//printing mistake in
    book
```